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ANALYSIS OF SELF-REPORTED SLEEP PATTERNS IN A SAMPLE OF US NAVY SUBMARINERS USING NONPARAMETRIC STATISTICS

by

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Fatigue contributes to increased accidents and mishaps and reductions in human performance. Inadequacies in the quality and quantity of sleep amongst US Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance. The purpose of this study is to gain insight into the sleeping habits of US Navy submariners. Using data supplied by the Naval Submarine Medical Research Laboratory, this study evaluates what a sub-sample of this population think about their sleep habits and will determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave. The statistical analysis showed that there are discernable differences in the quality and quantity of sleep onboard US submarines. There is a positive correlation between the amount of sleep obtained and the desired amount of sleep to function at every operational condition. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions. Finally, there is a positive correlation between the amounts of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep needed to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the 'at sea' condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

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ANALYSIS OF SELF-REPORTED SLEEP PATTERNS IN A SAMPLE OF US NAVY SUBMARINERS USING NONPARAMETRIC STATISTICS

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ABSTRACT

Fatigue contributes to increased accidents and mishaps and reductions in human performance. Inadequacies in the quality and quantity of sleep amongst US Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance.

The purpose of this study is to gain insight into the sleeping habits of US Navy submariners. Using data supplied by the Naval Submarine Medical Research Laboratory, this study evaluates what a sub-sample of this population think about their sleep habits and will determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave.

The statistical analysis showed that there are discernable differences in the quality and quantity of sleep onboard US submarines. There is a positive correlation between the amount of sleep obtained and the desired amount of sleep to function at every operational condition. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions. Finally, there is a positive correlation between the amounts of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep needed to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the 'at sea' condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

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EXECUTIVE SUMMARY

Fatigue contributes to increased accidents and mishaps along with reductions in human performance. In our modern military forces there is increasing complexity and advances in controls and visual displays for information. Today's sailor is tasked with processing more information and making decisions more quickly than ever before. It is recognized that certain military units, such as submariners, are especially vulnerable to the stresses imposed by these changes.

Inadequacies in both the quality and quantity of sleep amongst US Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance. Excessive fatigue can detrimentally affect operational readiness by altering mood, lowering job performance and communication skills and reducing motivation. The purpose of this study is to gain insight into the sleeping habits of US Navy submariners and to assess what a sub-sample of US Navy submariners think about their sleep habits and to determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave.

This analysis is limited to submariners who have spent time (greater than 1 year) aboard a Fleet Ballistic Missile Submarine (SSBN) or an Fast Attack Submarine (SSN). Correlation tests were used to determine if there was a relationship between total sleep obtained, uninterrupted sleep obtained and the desired amounts of sleep to function. The Friedman test and the Page test for ordered alternatives were used to determine if there were any discernable differences between the operational conditions. Finally, in the cases where the Friedman test resulted in statistically significant results, multiple comparison testing was used to determine which condition or conditions were different.

Both nonparametric tests yielded statistically significant results and showed that there are discernable differences in the quality and quantity of sleep aboard US submarines. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions. Finally, there is a positive correlation between the amounts

of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the ‘at sea’ condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

I. INTRODUCTION

A. OVERVIEW

Are sleepiness and fatigue inherent in a military lifestyle and a consequence of time spent at sea? Recent articles in Navy Times (2001) and Navy Medicine (2001) have highlighted a growing concern about the sleep deprivation and fatigue problems faced by military forces. While the primary focus of their article is on the clinical treatments available to sailors experiencing excessive daytime sleepiness, Bradshaw and Devereaux (2001) highlight the growing number of young and otherwise healthy military personnel beset with sleep disorders. They state that sleepiness results in poor job performance, accidents, and psychosocial dysfunction. (Bradshaw and Devereaux, 2001).

McMichael (2001) describes the impact of fatigue on enlisted aviation sailors serving aboard US Navy carriers. McMichael found that "the amount of rest afforded sailors also depend on the tempo of operations." The expectation of long working hours is a shipboard norm that rarely receives mention until serious injury, loss of life or damage to equipment warrants an investigation. Intense operational tempos with maximum hours of work followed by little rest tax the ability of sleep-deprived supervisors to monitor the fatigue levels of their subordinates.

While the onus of monitoring fatigue of personnel falls on the immediate or first line supervisors, how can they be expected to discharge this responsibility effectively and achieve mission accomplishment? A key characteristic of sleep deprivation and fatigue is that the sleep-deprived individual may fail to accurately assess his/her own personal performance degradation and may also fail to accurately assess his/her subordinates' level of alertness. How can supervisors employ effective sleep management techniques to limit the amount of fatigue experienced by themselves as well as other sailors? Chapter II outlines sleep management techniques generated from previous research and highlights signs of diminished physical and mental alertness.

B. BACKGROUND

Beneath the renewed interest in sailor fatigue is the knowledge that fatigue contributes to increased accidents and mishaps along with reductions in human performance. With increasing information complexity and advances in controls and visual displays in our modern military forces, today's sailor is tasked with processing more information and making decisions more quickly than ever before. "Rightsizing" has led to force cutbacks, resulting in fewer personnel and longer work shifts. It is recognized that certain military units, such as submariners, are especially vulnerable to the stresses imposed by these changes. However, it is still unknown how widespread the fatigue problem is in today's military forces. In addition, we do not know if military members believe that a problem exists.

C. OBJECTIVES

The purpose of this thesis is to assess what a sub-sample of US Navy submariners think about their sleep habits and to determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave. Additionally, an evaluation of the differences between amounts of desired sleep and actual sleep obtained at sea gives an indication of the fatigue level among the submariners sampled. And finally, the question of satisfaction with current watchstanding practices is addressed.

D. PROBLEM STATEMENT

Inadequacies in both the quality and quantity of sleep amongst US Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance. Excessive fatigue can detrimentally affect operational readiness by altering mood, lowering job performance and communication skills and reducing motivation.

This thesis describes an analysis of the Naval Submarine Medical Research Laboratory (NSMRL) survey (Appendix F) administered to U.S. Navy personnel assigned onboard the USS Providence or visitors to the Navy Ambulatory Care Center in Groton, CT. The following questions are explored:

1. Are there discernable differences between hours of sleep in various operational environments?
2. Are there discernable differences between the amount of sleep reported by the sailor as necessary to function at the "best" level and the amount of sleep obtained in 24 hours?

E. SCOPE AND LIMITATIONS

The purpose of this study is to gain insight into the sleeping habits of US Navy submariners. Results described in this thesis cannot be generalized to the entire submariner population because the extent to which the submariners who were surveyed are typical of US Naval submariners in general is not known.

Chapter II provides a review of the scientific and military literature on fatigue and sleep-related research. Additionally, information and recommendations are provided to address supervisory responsibilities in managing sleep and fatigue related problems. The methodology and demographic data of submariners that were surveyed is presented in Chapter III. The analytical strategy and statistical results are discussed in Chapter IV. Finally, conclusions and recommendations for future work are presented in Chapter V. Appendices provide supplemental information that may be useful to augment material presented in this thesis.

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II. LITERATURE REVIEW

The literature on human performance and fatigue is extensive. A complete review of this subject area is beyond the scope of this thesis. However, an overview of the field is essential to the understanding of this area. Specifically, this thesis will review human circadian rhythms, fatigue treatment strategies, US and foreign military fatigue research as well as community and industry specific fatigue research. Fitness for duty assessments will also be covered in this review. The reader may refer to Lauer (1991) and Naval Health Research Center (NHRC) Reports listed in the references and bibliography for a thorough review of terminology related to sleep deprivation and fatigue.

A. NORMAL CIRCADIAN RHYTHMS

The earliest studies of human performance and natural rhythms date to the late 1800s according to Gillooly, Smolensky, Albright, Hsi and Thorne (1990). Much work has been done over the past hundred years on fatigue and sleep patterns. Humans have various physiological and psychological processes that operate on circadian, ultradian and infradian rhythms. These three terms refer to the cycles that operate on a period of a day, less than a day and more than a day, respectively (Monk and Folkard, 1992). Today, sleep researchers generally state that the human circadian rhythm operates on a 24-hour clock. This temporal average (the actual time varies between 23 and 25 hours) is observed for physiological, behavioral and performance measures (Monk, 1990).

Humans are primarily diurnal creatures who experience primary and secondary peaks (1200 and 2100 hrs) and primary and secondary troughs (0300 to 0600 hrs and mid-afternoon) in their circadian rhythms. This natural inclination to perform at peak performance during the day and sleep during periods of "environmental darkness" runs counter to typical work schedules in the US Navy (Tepas, 1989). There are exceptions to this pattern seen in persons with sleep disorders (e.g., disruptions of sleep during natural/normal night times) as well as those who simply 'prefer' to be awake at night.

The social and physical zeitgebers (circadian time cues), age and personal preference ("owl vs. lark") both contribute to the individual circadian rhythm. While individual differences accounts for some of the variation of the circadian clock, shiftworkers and military members at sea often find themselves experiencing excessive sleepiness and fatigue due to the additional stress posed by rapid changes of watch rotations.

B. HUMAN PERFORMANCE VARIATIONS THROUGHOUT THE DAY

Many parts of the human body are affected by sleep loss. NHRC Report 89-46 by Naitoh, Kelly and Englund (1989) describes the effects on the following biological systems: metabolism, adrenocorticalcal activity, autonomic activity, hematological/immunological changes, adrenomedullary activity, epileptiform discharges, and working capacity. Most of these topics are inappropriate for in-depth discussion in this thesis. However, it is important to realize that continuous sleep loss can manifest itself in illness of the mind and body. Successful treatment and remediation techniques should focus on physical, mental and social areas. An interesting point to note from this study was that total sleep deprivation was found to have some positive effects on depressed patients when exposed to extended periods of wakefulness. This study was conducted in a medical treatment facility with patients experiencing some form of depression and should not be attempted at home.

Many research studies have examined the impact of total or partial sleep deprivation of nocturnal sleep and its impact on human performance (Angus and Heslegrave, 1985; NHRC Report 87-21, 1987; Condon, Colquhoun, Plett, DeVol and Fletcher, 1988; Krueger, 1989). This information is particularly useful for people experiencing serious sleep disorders and may also be helpful in understanding appropriate treatment options. Due to the intrusive and exhaustive procedures required to gain accurate and useful data, many researchers prefer to obtain a baseline of performance and then proceed with laboratory protocols and testing during total sleep deprivation. While many of the effects on performance may be the same, the cumulative

effects of consistent and partial sleep deprivation are impossible to duplicate in the lab environment. The information gleaned from these studies shows that more serious performance degradation occurs with heavy mental workload and decision-making (e.g., cognitive tasks) vice physically demanding tasks. Naval leadership can use this information to determine which ratings are at greater risk of injury or detriments in performance during periods of sleep loss. Later in this chapter, testing done to simulate military operations will be presented.

In a report for the Office of Naval Research (1974), Woodward gave a thorough analysis of research done on sleep loss. His insightful analysis addressed many problems, as well as questions about unknown interactions of sleep loss and performance. Interestingly enough, although a century has passed, Woodward's assessments are still valid. Briefly stated, Woodward found that performance degradation depends on several controlled and uncontrolled variables: the amount of sleep loss, the type of task performed and other environmental stressors. More importantly, the amount of sleep needed for full recovery to peak performance is often underestimated and underachieved. Depending upon the length of the period of sleep loss, a typical eight-hour recovery time is inadequate. Factoring this into already overly tasked and under-manned departments, this type of work-rest schedule would be ineffective or impossible to sustain in an environment such as that posed by the USN submarine community.

C. MEASUREMENT TOOLS AND PERFORMANCE INDICATORS

1. Measurement Tools

There are many different tools available to sleep researchers that can be used to assess levels of fatigue, wakefulness, body temperature, hormonal changes or performance degradation on cognitive, physical and/or complex tasks after sleep loss periods. These tools range from subjective, self-ratings/self-reports to the more objective measures of physiological changes and performance through vigilance, psychomotor, physical and cognitive tasks. Many studies in the literature review used a battery of

measurements to measure sleep latency and/or wakefulness and therefore reported different measures of performance degradation. Appendix A gives a brief list of the tests reported in current research testing environments.

2. Performance Indicators

Many vigilance tests report that reaction time and performance were improved after naps. Interpretation of research protocols and experimental design are necessary in that confounding variables such as (e.g., motivation, age) are present in performance based testing. The length of the task is also an important variable to be considered because tasks with too short a duration may show a moderate improvement that drops off substantially after ten minutes (Harrison and Horne, 1997). Designs such as these are not representative of actual working environments where individuals are expected to perform certain tasks longer than ten minutes (e.g., monitoring tasks, critical decision-making, learning a new task). This highlights a noted deficiency between field studies (observations made in the actual working environment) and laboratory studies (observations made in a laboratory with tasks designed to simulate the working environment). One compromise to counter the weaknesses of both designs occurs with the hybrid study that takes actual operators from a particular field and attempts to simulate their actual working environments.

A variety of performance indicators that were indicative of sleep deprivation were found in this literature review and were a function of the measurement tool chosen by the researcher. Other variations that were seen occurred depended upon individual differences among subjects (including normal sleeping habits versus sleeping disorders) and upon the research measurement of total sleep loss versus total period of wakefulness. For example, if the typical workday/shift starts at 0700 and the person is expected to work until 0700 the following morning, the amount of sleep loss is equivalent to one night of sleep deprivation (approximately eight hours). Similarly, the person has been in a state of wakefulness for at least 24 hours. Typically, the study findings will report either sleep loss or wakefulness and it is important to understand this difference

contextually. Additionally, the periods immediately preceding duty can also be included in the period of wakefulness provided the person did not commence duties after normally scheduled sleep periods.

There are key differences between the levels of degradation in cognitive tasks when compared to physical tasks. It is no mystery that excessive sleepiness can lead to poor performance. If a person suffers from chronic sleep deprivation or fatigue he/she may experience personality/mood changes, decreased alertness, difficulty in decision-making, changes in speech communication and verbal ability, overall lack of motivation for task, inattention, inability to concentrate and increased numbers of unplanned naps, lapses or microsleeps.

D. INTERVENTIONS AND TREATMENT STRATEGIES TO COUNTER FATIGUE

Two basic approaches to mitigating the effects of fatigue due to sleep loss include the prevention of sleep loss and/or getting additional sleep prior to or immediately following a period of sleep deprivation. Both of these approaches are overly simplistic in their methodology and fail to address the underlying causes that led to sleep loss (e.g., social, physical or environmental factors). Of the many approaches listed in the various research studies, only those available and appropriate for military personnel will be addressed in this thesis. The use of lighting (bright vs. dark) to enhance wakefulness is operationally infeasible for submarine forces and will not be discussed.

1. Use of Medications

Various forms of medications are available to aid in the onset of sleep and to maintain wakefulness. Over the counter remedies would include both sleeping pills and caffeine. Other varieties would be nicotine and herbal/natural additives. Both their potential for increased performance and potential for side effects will be discussed.

Additionally, studies of hormone secretions (e.g., melatonin and cortisol) have also been used to measure circadian rhythm and will be discussed briefly.

a. Caffeine

Numerous studies have been designed to test the effects of caffeine and other performance enhancers (e.g., tyrosine, creatinine, flutamine, choline, and antioxidants) for use by military subjects in the operational environment (Lamberg, 1999). Some of these products are designed for military members in field conditions and would not necessarily be needed for submarines (e.g., food replacement bars or military rations). However, the use of caffeinated products such as sodas, coffee, gum and caffeine supplements could be readily available to submariners. Further research needs to be done to assess the actual impact on performance. The actual amount of caffeine available in an average cup of coffee varies from 100 mg to 200 mg. See Lamberg (1999) for detailed information on various studies of caffeine remediation techniques.

Studies designed to replicate the military environment have varied in the research design and therefore yielded results that may not be applicable to actual military operations. Bonnet and others (1995) have completed a study that compared the effects of caffeine to naps. This research design identifies naps as a 'drug' that increases alertness. While Bonnet supports the use of scheduled naps vice pharmacological interventions, he makes the following assertion:

> Napping on night duty, even if one's workload permits, may harm rather than help alertness because sleep deprived people sink quickly into deep sleep. When awakened abruptly, they often experience sleep inertia or 'mental fogginess'.

b. Melatonin and Cortisol

The most common measurement of human circadian rhythm has been body temperature, which has been collected predominantly using sublingual (under the tongue) readings due to its ease of use. Increased hormone levels of both melatonin and

cortisol have also been found to correspond to the circadian troughs and peaks, respectively. Separate studies have measured performance measures along with melatonin and cortisol profiles after one night of sleep deprivation. (Goh, Tong, Lim, Low and Lee, 2001). Significant increases in melatonin and cortisol levels were noted around 1330 on the day after nighttime sleep deprivation with an increase in salivary secretion of melatonin than cortisol. This study showed significant hormonal changes but these did not affect performance measures of certain psychomotor and physical tasks. The time of day is important in understanding increased levels of melatonin and its accompanying feelings of daytime sleepiness due to the sleep-inducing properties of melatonin. Some herbal varieties of melatonin exist and are primarily used by persons experiencing jet lag. Additional research needs to be done comparing the sleep inducing properties of melatonin vice other sleep inducing drugs.

2. Napping

There are no behavioral models that can definitively predict the positive effects of napping (Naitoh and Angus, 1987). Data that promote the benefits of napping are in direct conflict with studies focusing on the circadian cycle and the side effects of napping at inappropriate times. Questions pertaining to the proper placement and duration of naps have been studied. One question is whether some sleep always better than no sleep. Is there a minimal amount of sleep that must be obtained before performance improves? Are daytime naps more beneficial than nighttime naps? Can sleep be stored? And if so, does a nap prior to prolonged periods of wakefulness improve performance? Most of the literature attempted to answer some of these questions individually and collectively. No definitive results could be found that conclusively answered all of the questions. The studies did provide valuable insight on using naps as a tool for fatigue management. Detailed interpretation of the results would be more suited for a descriptive analysis on the process of napping and are not included in this thesis.

Bonnet, Gomex, Wirth and Arand (1995) completed a study that directly compared the effects of caffeine and naps. The naps were at four levels: 1) zero hours, 2) two hours, 3) four hours and 4) eight hours while caffeine was administered at three levels: 1) placebo, 2) 150-300 mg, and 3) 400 mg. An interesting point is the inclusion of the eight-hour nap condition. Traditionally, eight hours is considered to represent the total requirement for nighttime sleep. In the case of recovery sleep, an eight-hour sleep period could be correctly classified as a nap. The findings of this research are presented below. For purposes of this thesis, a nap is considered to be any sleep period less than that of an individual's normal sleep period. Brief sleep periods known as microsleeps, ultrashort sleep periods, lapses (phrase coined by Walter Reed Army Institute of Research) and prophylactic sleep are similar to naps in that they represent brief periods of sleep (very few seconds or minutes) which occur during prolonged periods of wakefulness and have no recuperative properties. While these fit into the broad definition of naps (short sleep periods less than normal sleep amounts), they are inappropriate for discussion as viable intervention strategies.

The purpose of the Bonnet research was to determine if there was an improvement in performance based on the use of caffeine and prophylactic naps during prescribed periods during the day after significant sleep loss. As expected, the 8 hour nap condition presented the greatest performance increase of all caffeine and nap conditions presented. The 2-4 hour nap conditions and 150-300 mg of caffeine produced comparable results. The researchers also used the Multiple Sleep Latency Test (MSLT) and determined that "latencies were longer in the higher 'dose' conditions than in the lower 'dose' conditions and all groups differed from the placebo (Bonnet et al, 1995). Finally, the time of day and time of treatment significantly impacted performance measures. One interesting note of this research centered upon the fact that the most beneficial effects were noted during the first night of sleep deprivation.

Dinges, Orne, Whitehouse and Orne (1985) report that certain tasks sensitive to lowered alertness had improved reaction times within a 56-hour period of wakefulness. Some researchers report a difference in the performance improvement as related to the time and placement of the nap within prolonged periods of wakefulness. Sometimes the

reports would also include information on the initial detrimental effects of sleep inertia on performance followed by performance improvement. These results were countered by work reported in NHRC Report 89-49 (1989) that suggested that naps could prevent 'behavioral freezing' (lapses of temporary mobility in an emergency situation). It is important to note that a relationship exists between the placement of the nap and the amount of improvement. Naps taken at night, after prolonged wakefulness, are less beneficial because they occur during the circadian trough. Sleep inertia effects may be more pronounced and the person may have increased feelings of fatigue. Additionally, Gillberg, Kecklund, Axelsson, and Akerstedt (1996) report that all naps greater than 15 minutes were beneficial and that increases in duration from 60 minutes to 120 minutes did not increase alertness measures. Incidentally, the improvements were noted only four hours after the nap. This is useful to first line supervisors responsible for monitoring sleep loss and managing subsequent scheduling to improve mission accomplishment. Immediate improvements may not be noted as quickly as required for dangerous assignments.

E. COMMUNITY SPECIFIC RESEARCH

Much of the current sleep literature focuses on implications of sleep deprivation and fatigue within the broad categories of nuclear regulatory agencies, medical community, transportation and the military. The production and manufacturing industry has also produced notable results in the evaluation of shiftworkers. The results and techniques identified in the first three environments are most similar to the military in that workers often perform dangerous tasks where the performance degradation can have fatal or catastrophic consequences.

1. Nuclear Regulatory Agencies

Recent disasters at Chernobyl, Three Mile Island, Davis-Beese and Seco reactors all had common elements. Prior sleep loss by key personnel led to their inability to correctly identify or implement necessary safety features incorporated into the system

design. The failure to correctly assess appropriate courses of action with unexpected and unusual malfunctions was a direct reflection of the limitations of decision-making in sleep deprived individuals (Harrison and Horne, 2000). Quantitatively, it is impossible to separate out the impact of human errors versus equipment failures. However, it is safe to say that the fatigue levels combined with the associated job stress are key factors in the quantity and quality of errors. Lauer (1991) points out the similar characteristics among these types of organizations and military operations:

> [A]ll operate twenty four hours per day, all have shifts that work when their biological clock indicates they should be asleep, and each organization works within very unforgiving environments where mistakes are rarely without consequences.

2. Medical Community

The medical community is also faced with rotating and shifting schedules requiring immediate and potentially life-threatening decisions in emergency environments. The literature specific to the medical field has focused on both the health effects of prolonged periods of sleep deprivation and the effective management of work-rest cycles for maximum performance. As with the military environment, medical professionals often sleep within the confines of the work environment for immediate recall onto duty. These short sleep episodes are in no way protected to ensure that adequate rest has occurred. Additionally, these professionals are expected to battle with sleep inertia while making life-threatening decisions very quickly. The problems with degraded decision-making capabilities along with degraded speech communications are similar to those experienced by some military personnel.

3. Transportation Industry

Various departments within the transportation industry have focused on intervention strategies to mitigate the harmful and dangerous affects of sleep deprivation. The studies have involved the aviation, railroad and trucking industries in particular. Much attention has been given to the aviation industry in support of crew rest for pilots

and air traffic controllers in both the civilian and military environments. Less attention has been given to the support personnel required to maintain the aircraft and its schedules.

Similarly, the trucking industry has focused on management of the drivers expected to travel great distances during the night that corresponds to the circadian trough in the human rhythmic cycle. Their reports have found that "fatigue related impairment is not dissimilar to the effects of moderate alcohol intoxication." (Centre for Sleep Research, 1999). This report found that 17 hours of wakefulness is equivalent to .05% blood alcohol concentration (BAC) and 24 hours of wakefulness is equivalent to .10% BAC.

The effects of impairment due to drug/alcohol abuse are well documented. Employees and sailors would face harsh disciplinary and criminal actions if found intoxicated in the workplace. Detriments in performance due to sleep deprivation are oftentimes viewed as necessary and unlikely to prohibit mission accomplishments. A direct comparison of the performance similarities from criminal activities (e.g., drinking on the job) and prescribed working conditions (e.g., excessive periods of sleep loss) may improve an organization's desire to manage fatigue.

4. Military

Several foreign and domestic authors and organizations have done significant research on military operations. Brief synopses of their findings are listed below. Distinctions between sustained operations and continuous operations were made and are defined here to facilitate understanding of the material. Krueger (1989) defined sustained operations (SUSOPS) as unplanned and unusually long work periods that must be continued until a goal is reached. He went on to state that continuous operations (CONOPS) were those uninterrupted schedules of non-stop activity and a subset of SUSOPS.

Lamberg (1999) restated the obvious changes of the past two decades in the look and feel of the military battlespace (e.g., use of technology to enable 24 hour operations).

In addition to the technological improvements of military hardware, there should also be improvements in the design of equipment that allows for the minimization of errors and increases in cross-training abilities for adequate work-rest cycles. NHRC Report 89-49 (1989) addressed the question of minimal sleep requirements for SUSOPS and identified the smallest amount of sleep (sleep quantum) as a measure of quantity (e.g., minutes) vice quality (e.g., sleep stages). Military professionals interested in sleep management/sleep logistics are most concerned with the "operational merit of providing short sleep breaks at a particular time of day after so many hours of continuous work during a mission" (NHRC 86-22, 1986).

Works by Stolgitis (1969), Lauer (1991), Chapman (2001) and Colquhoun (1968, 1969, 1985 and 1988) along with reports from the Naval Health Research Center and Walter Reed Army Institute of Health address sleep deprivation and fatigue amongst various sections of the maritime and military populations. The initial work by Stolgitis compared the four-hour watch rotation with six-hour watch system. The six-hour watch schedule has become common since his initial research. It provides a longer period of time for nighttime sleep on the third day of rotation and was most preferred by crew members.

Lauer evaluated a segment of the surface warfare officer (SWO) community assigned to shipboard command and control functions in a certain operational condition. He reported that a great percentage of the tactical action officers (TAOs) and officers of the deck (OODs) experienced systems of sleep deprivation while underway and a very small percentage of the TAOs and OODs felt they were fully alert at all times. The restricted nature of Lauer's thesis prevents full publication of actual percentages; authorized personnel should refer to his thesis for specific numbers.

Chapman evaluated the relationship between fatigue, performance and safety. She identified several stresses amongst submariners in the Australian Navy that are equivalent to those found amongst US Navy submariners: 1) living and working in confined spaces, 2) long separations from family and/or social network, 3) inability to use leisure time effectively, 4) exposure to various chemicals and pollutants, 5) frequent sleep

disruptions and 6) overall fatigue. In her observations of 25 subjects, the following deficiencies were noted in submariners:

> 1) slowed speech, 2) delayed response to orders, 3) greater number of malapropisms and incorrect sequencing of orders, 4) delayed repetition of orders, 5) failure to acknowledge orders, 6) increase in vacant stares, irritability and minor altercations between personnel, and 7) decreased ability to acknowledge multiple sources of information during longer periods at sea.

Chapman noted many techniques available for military supervisors in the submarine community. Supervisors should receive continuing education on the impact of fatigue and performance, be aware of the effects of sleep inertia and monitor the interactions between crewmembers. As mood declines, so do the amount of communications. This decline is especially critical during watch turnovers, particularly during the circadian trough. She suggests that supervisors should avoid assigning non-urgent tasks during off-duty periods and they should use a fatigue checklist in conjunction with sleep logs kept by sailors to allow for adequate sleep prior to watchstanding duties. This places an added administrative burden on supervisors and would have to be supported from the highest command levels.

In planning a suitable watch schedule, the direction, length and speed of rotation are factors that can increase the levels of fatigue. The direction of the watch rotation should be in a forward direction so that the 'day' period is longer than the 'night' period. The mid-watch and other variations that start or end during the circadian trough are dangerous in that personnel are more tired and 'out-of-sync' with the natural biological rhythm.

The speed at which shifts are rotated have received much attention. Many researchers support slow rotation (i.e., the same schedule for longer period of time) over the rapid rotation schedule that is prevalent in the military. Individual preferences and social demands may impact personal choice but is less of a factor for submariners who have limited social opportunities at sea.

Studies done to determine the most effective watch schedule for maritime workers also have mixed results. As stated earlier, Stolgitis (1969) compared the four-hour watch schedule with the now popular six-hour schedule. Today, the six-hour (18-hour day) schedule has been under scrutiny. Should this watch rotation be modified to a 24-hour day? NHRC Report 96-2 (1996) provides preliminary findings on submariners and the 18-hour day schedule. The intent of this study was to determine if the submarine environment was conducive to 'free-running' human circadian rhythm where each individual adapts to his own unique cycle. This study used actigraphs (equipment designed to monitor movement and indicate periods of sleep), sleep questionnaires, sleep logs, saliva samples, and computer performance testing.

Gill, Hunt and Neri (NHRC Report 96-2, 1996) found that submariners were able to "obtain adequate sleep and maintain adequate performance while working the 6-on/12-off schedule." This finding also reports that the average amounts of sleep obtained depended upon the stages of deployment with average sleep periods of five and a half hours per sleep episode. Despite the diminished amounts of sleep, they further report that no negative effects were found in mood or alertness. This finding runs counter to the general opinion that eight hours of sleep are necessary for full recuperative effects. The limitations to this study include: small sample size (N=29), small segment of this sample on the 18-hour schedule (N=19), small segment of the sample who completed sleep questionnaires (N=20), those who wore actigraphs (N=10), and the short period underway (6 weeks).

F. SUMMARY

Despite the specialized training of military professionals, senior leadership cannot assume that competence, professionalism and motivation of personnel will compensate for performance degradation and fatigue after sustained periods of sleep loss. Recognizing that rapid watch rotation prevents persons from adjusting to the schedule, there is an increased potential for errors through lack of communication and motivation. The lowered levels of alertness may be temporarily offset with caffeine and the use of

naps. Supervisors should incorporate napping periods during SUSOPS/CONOPS, as much as practical, keeping in mind the side effect of sleep inertia. A constant balance between mission accomplishment and fatigue management can ensure that submariners are given every opportunity to perform at maximum levels without diminishing safety or increasing risk of injury.

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III. METHODOLOGY

A. OVERVIEW

The objective of this thesis is to evaluate submariner perception of sleep deprivation in a variety of schedules within the operational environment. This research involves analysis of the collected survey results from shore and sea based submariners in Groton, CT. The data sets for both groups have been combined and the analysis will determine if the same patterns of sleep and feelings of fatigue are present. Any similarities between groups may provide useful information for intervention strategies and possible improvements in work-rest schedules.

B. DATA COLLECTION

1. Instrument

The instrument used for data collection was the Naval Submarine Medical Research Laboratory (NSMRL) Watchstanding Survey (see Appendix F). It was originally designed by SurgCDR Steve Ryder of the Royal Navy and was later modified by Dr. Christine Schlichting under Office of Naval Research (ONR) sponsorship. The current effort began in October 2000 under the sponsorship of ONR via CDR Steve Ahlers and also has the support of Commander Submarine Group Two (COMSUBGRU TWO). This effort originated from the ideas and initiative of SurgCDR Ryder and Dr. Schlichting. CDR Wayne Horn and LT Jeff Dyche serve as the principal investigators of this study designed to evaluate improvements on the quality of life (QOL) and performance of US Naval submariners via manipulation of the watchstanding schedule.

The survey contains 37 questions with six demographic and submarine work-rest schedule related questions. The final two questions are free response questions pertaining to the current watchstanding routine. Demographic questions cover current duty assignment, age, rank, rating, submarine qualification, number of children under the age of five, nuclear designation, and current watch schedule. The remaining questions

pertained to the habits and schedule at four conditions: 1) at sea, 2) in port, 3) on shore duty and 4) on leave. The expected responses were either a direct answer to a specific question (e.g., How many hours of sleep, per 24 hours, do you think you need to function at your best?) or used Likert scaling of never, rarely, sometimes, often, frequently or always.

2. Subjects

Surveys were administered to sailors assigned to either the USS Providence or receiving care at the Naval Ambulatory Care Center (NACC), Groton, CT. The two separate data collections ($N_{Clinic1}$=47 and $N_{Clinic2}$=27) at NACC were pooled with the subjects from the USS Providence (N_{Sub}=93).

C. DATA ANALYSIS

1. Data Tabulation

Survey demographics and responses were hand entered into Microsoft® Excel 2000 spreadsheet. Each row represented the responses of one subject. The columns were the survey questions. Survey questionnaire items that have no response are coded with NA and are dealt with by S-PLUS 2000© (MathSoft, Inc.) as the data is transformed into an S-PLUS 2000© data frame for complete data analysis.

2. Statistical Analysis

This analysis is limited to submariners who have spent time (greater than 1 year) aboard a Fleet Ballistic Missile Submarine (SSBN) or an Fast Attack Submarine (SSN). Basic summary statistics were developed and bar charts were used for initial familiarization of data points and possible identification of problems associated with the data set. Descriptive analysis is provided to describe basic and general information about

the demographic and specific question results. Where appropriate, the results include the distribution of survey participants by age and rank classifications. As the results for categories included non-numerical options (e.g., 4 or less, 9 or more), the total sample, means and standard deviation for questions 7, 9, 17a, 17b, and 18 could not be ascertained.

In most cases, the categorical data specific to the amount of sleep obtained or desired was ordinal in nature. The intervals in between were represented by ½ hour increases. Another technique for future analysis would change "4 or less" to "4" and "9 or more" to "9". This technique puts upper and lower bounds on the actual values and may be useful for comparison to other research results.

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IV. ANALYTICAL STRATEGY AND STATISTICAL RESULTS

A. OVERVIEW

In this survey, data from 167 respondents was entered into a Microsoft Excel© database. The original Excel spreadsheet contained data input for 47 respondents and was sent to the Naval Postgraduate School (NPS) via e-mail by LT Jeff Dyche of the Naval Submarine Medical Research Laboratory in Groton, CT. The additional 120 surveys were mailed to NPS and incorporated into the existing database. In the submarine database, the columns corresponded to the questions and each row represented the subject response. The surveys were separated into three groups by the column identifier (ID) and numbered from 1-47, 1001-1027 and 2001-2093, respectively. Ambiguous answers (multiple responses for a single question, questions left blank, etc.) were verified in 120 of the surveys and the responses of the first 47 were assumed to be correct and valid.

Of the 167 surveys collected, 20 respondents indicated they had not spent any time on either type of submarine (SSN or SSBN). These 20 respondents were therefore eliminated from further statistical analyses due to the fact that the survey was designed to explore behavior and sleep patterns of submariners in the operational environment. Only data from respondents with more than one year of service aboard either a SSN or SSBN was evaluated. Additionally, since only four of the respondents were officers, these four respondents were also excluded from the study. The analysis focused on the remaining 143 surveys of enlisted submariners.

Subsection B of this chapter describes the data set by the key factors of age, rank, years of service aboard a submarine, watch schedule, and the reported sleep patterns. Two nonparametric tests were used to describe the patterns within operational environments and between subjects for selected questions. Analysis of survey questions concerning such things as drug use, headaches, and nicotine intake were considered outside the scope of the current thesis and has been left for future analysis. Tables listed

in Appendix C amplify information found in the text, together with additional bar charts and bar plots provided in Appendices D and E. Table 1 is provided as an easy reference to the specific questions addressed in this chapter.

Survey Number	Selected NMSRL Survey Questions
17a	How many hours Total Sleep do you usually get per 24 hours?
17b	On average, what is the longest period (in hours) of Uninterrupted Sleep you get per 24 hours?
18	How many hours of sleep, per 24 hours, do you think you need to function at your best?
19a	During your career have you ever momentarily nodded off while on watch?
19b	During your career have you ever seen a member of your crew momentarily nod off while on watch?
20	How often do you have difficulty falling asleep?
21	How often after falling asleep, do you wake-up early and can't get back to sleep again?
22	How often do you feel so tired on watch that you can't concentrate and need help staying awake?
23	How often do you feel physically or mentally tired during your watch?
24	How often do you feel tense or irritable during your watch?
25	How often do you have difficulty waking up or getting out of bed?
26	How often do you feel well rested after you wake up and get out of bed?
27	How often do you feel overly tired or have difficulty staying awake?
28	How often do you take naps?
30	How often after falling asleep do you wake up and go back to sleep?
31	Do you feel as though you get enough sleep?
33	How often do you make mistakes because you are tired?

Table 1. NSMRL questions selected for analysis

B. DATA CLASSIFICATIONS

1. Age

Figure 1 shows that the age distribution of the respondents is bimodal. The median response was the "25-26" age category. A plot of age conditioned on platform shows that while 26 of the respondents were not currently assigned to a submarine (or

failed to indicate such so NA was supplied as the response), the age distribution was the same and it was concluded that the groups were from the same population.

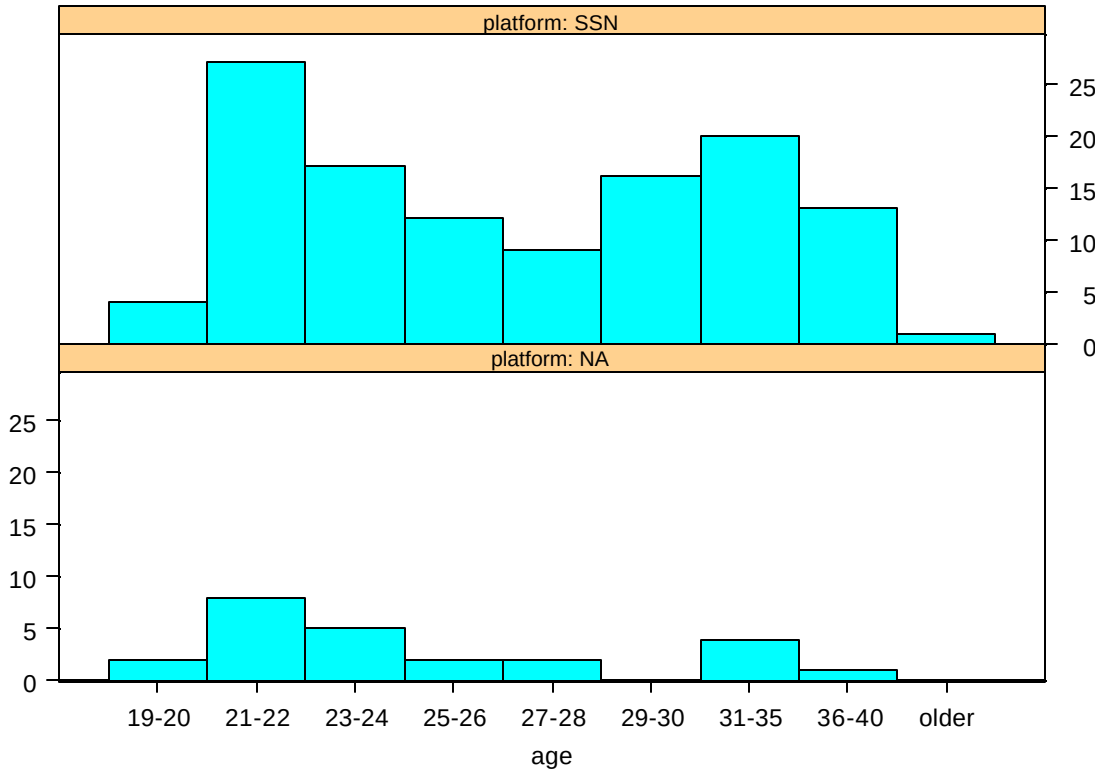

Figure 1. Histogram of Platform Conditioned on Age

2. Watch Schedule

Table 2 illustrates the watch schedules of the 143 respondents. Nearly 78% of the respondents (111/143) indicated the "6 on 12 off" response, which corresponds to an 18-hour day schedule. Question 34 was used to evaluate the feeling of satisfaction with the current watch schedule and 60% (81/ 135) were satisfied with the current watch schedule.

Reported Schedule	Number of respondents	Percentage of respondents
6 on 6 off	3	2.1%
6 on 8 off	1	0.7%
6 on 12 off	111	77.6%
6 on 18 off	3	2.1%
8 on 12 off	1	0.7%
9 on 9 off	1	0.7%
12 on 6 off	3	2.1%
12 on 12 off	8	5.6%
14 on 10 off	3	2.1%
24 hours	1	0.7%
No response	1	0.7%
Other	7	4.9%
Totals	**143**	**100.0%**

Table 2. Reported Watch Schedules

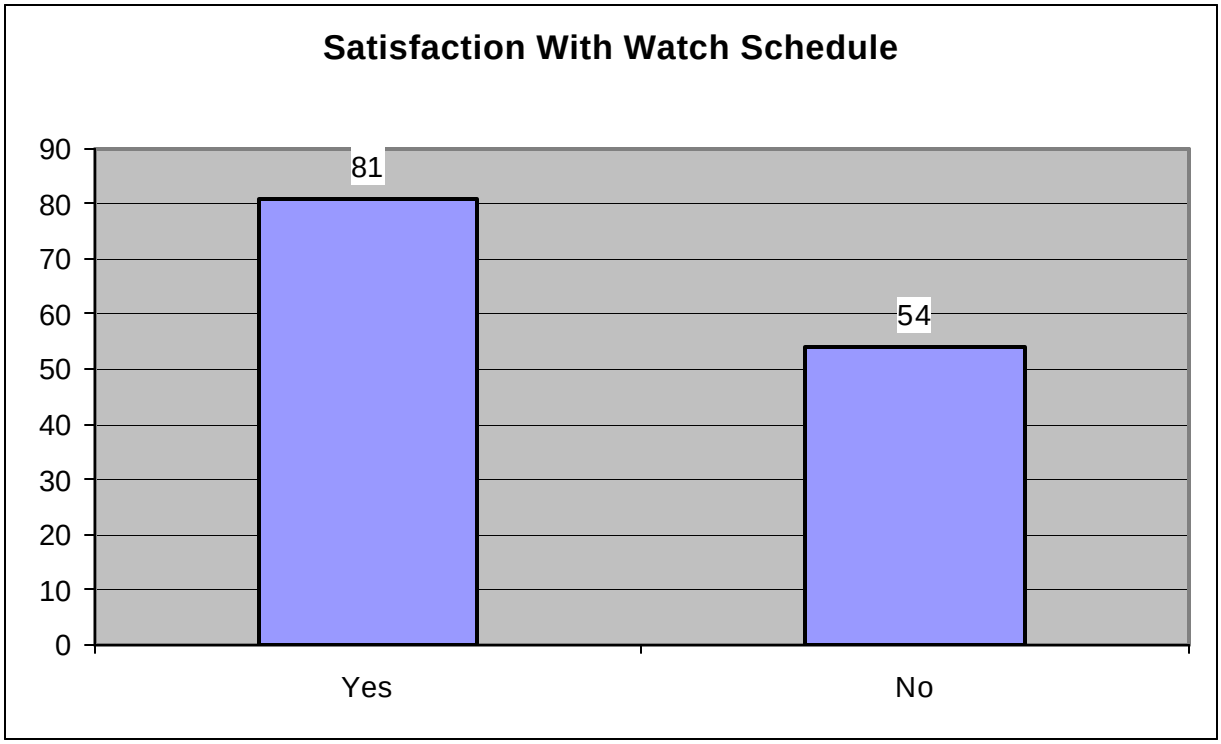

Figure 2. Satisfaction With Current Watch Schedule

3. Ratings and Ranks

The largest percentage of military ranks was among the E4 to E6 category (87%, 125/143). The distribution of military ratings was similar in the E4 to E9 categories with the largest percentage of seaman, MM and MS ratings in the E1-E3 category.

4. Platform

Most of the respondents reported serving aboard a nuclear submarine (SSN) while a few of the respondents had served aboard a fleet ballistic submarine (SSBN). Eighteen percent (26/143) of the respondents reported serving on both the SSN and SSBN platforms. Appendix C lists the years of service for each platform and Figure 3 gives a graphical representation of years spent on each platform. A combined total of 68 respondents left this entry blank for the SSBN and Shore categories. For these categories, blank responses are equivalent to zeros if a respondent never served on either platform. The removal of responses for which NA or blank responses were recorded for the Shore Duty question reduced the sample size available for subsequent analysis.

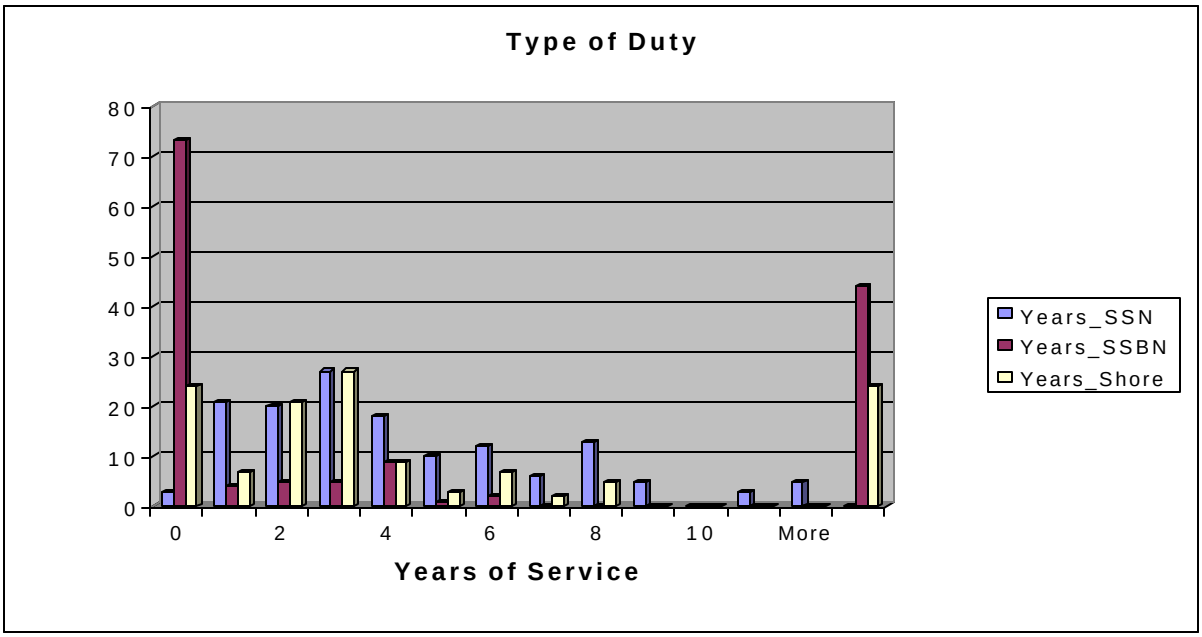

Figure 3. Bar Chart Of The Years Of Service By Platform

Time (years)	SSN	SSBN	Shore
0	3	73	38
1	21	4	7
2	20	5	21
3	27	5	27
4	18	9	9
5	10	1	3
6	12	2	7
7	6	0	2
8	13	0	5
9	5	0	0
10	0	0	0
11	3	0	0
More	5	0	0
NA	0	44	24
Total	**143**	**143**	**143**

Table 3. Years Of Service By Platform

5. Sleep Patterns

The purpose of this thesis is to determine if there are any discernable differences between reported sleep patterns at four levels (at sea, in port, shore duty and on leave). The data in questions 17a, 17b and 18 are ordinal in nature and were evaluated using nonparametric techniques (Conover, 1999). Responses with multiple or missing values were marked as "NA" and are removed from analyses. The factors in questions 17a, 17b and 18 are ordered in nature (e.g., "4 or less" hours is less than "4.5", "4.5" is less than "5", etc). Refer to Appendix F for a full listing of the survey questions.

Twenty-one correlation tests were used to compare questions 17a, 17b and 18 at each operational level. The subjects were divided into two groups based on the type of service. In Group A, 91 subjects reported service in all four conditions. In Group B, 129 subjects reported service in all conditions except shore duty. Spearman's ρ tests the linear dependence between conditions and equals one if there is "perfect agreement" (Conover, 1999). The amounts of total sleep, uninterrupted sleep and desired sleep to

function showed an increase in positive correlation (Spearman's ρ) at each condition. As uninterrupted sleep is a subset of total sleep, the positive correlation is expected. Tables in Appendix C list the total number of responses at each condition level for questions 17a, 17b and 18, respectively. The following four charts show the increasing correlation of Groups A and B and represent the results of fourteen correlation tests.

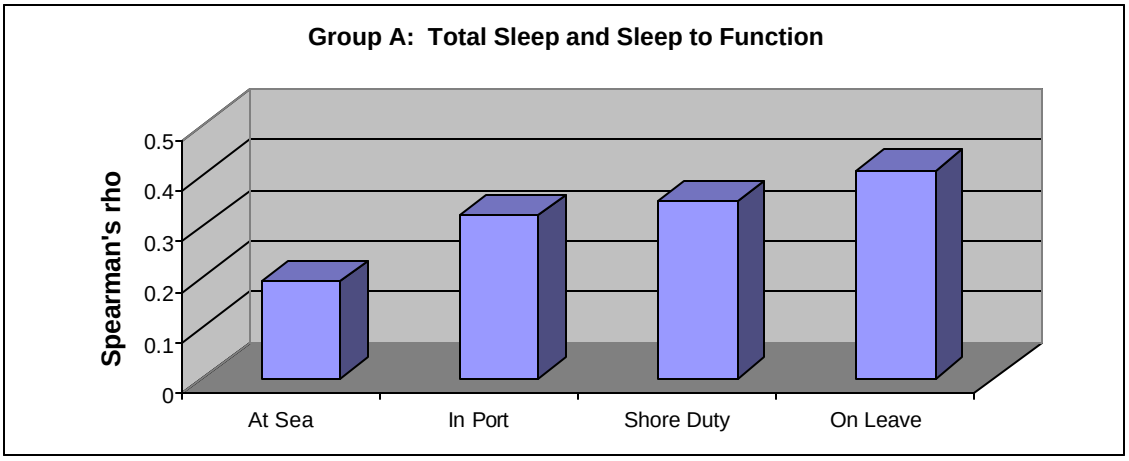

Figure 4. Total Sleep and Desired Sleep to Function (N=91)

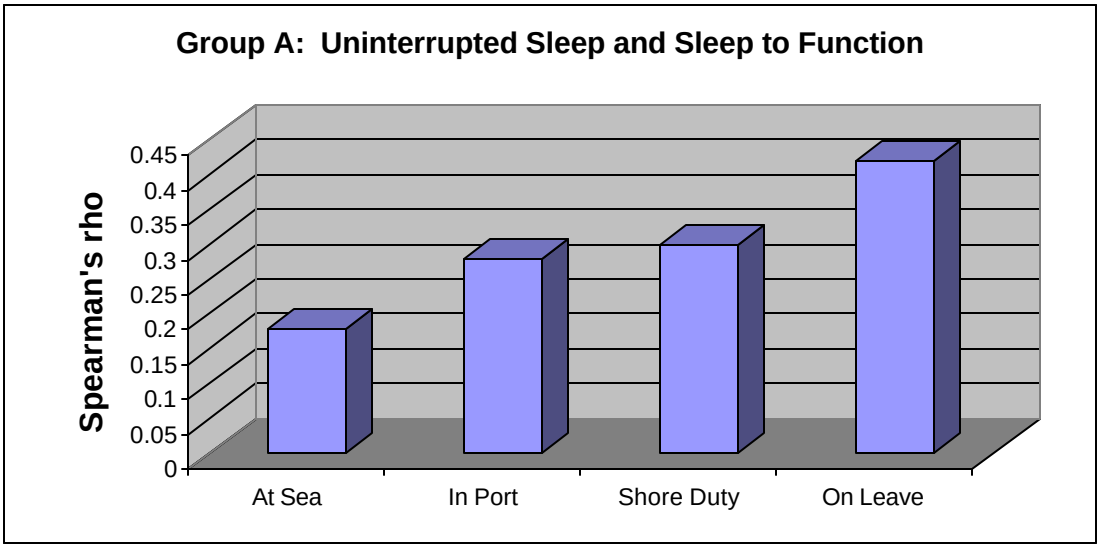

Figure 5. Uninterrupted Sleep and Desired Sleep to Function (N=91)

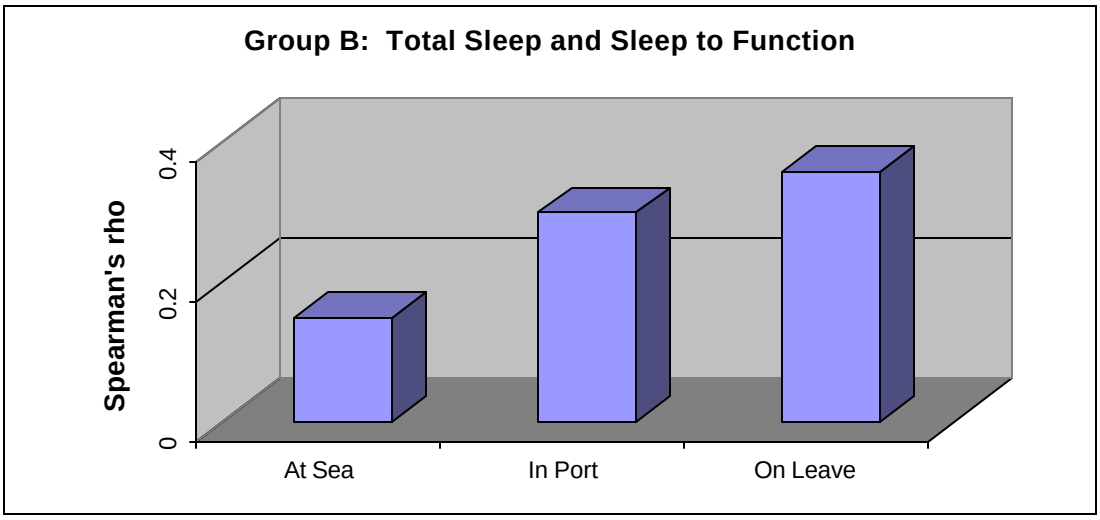

Figure 6. Total Sleep and Desired Sleep to Function (N=129)

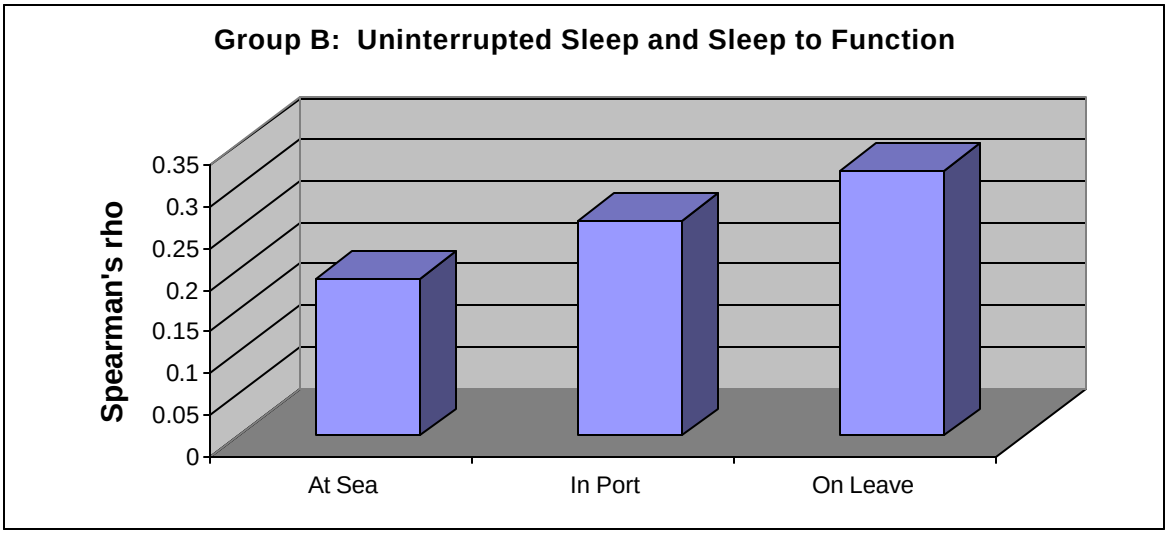

Figure 7. Uninterrupted Sleep and Desired Sleep to Function (N=129)

C. NONPARAMETRIC TESTS

The techniques chosen for this analysis were the Friedman Test and the Page Test for ordered alternatives. While ranking the individual responses for each subject, the Friedman test is used to test the assumption that the conditions have identical effects. Page tests the correlation between the Friedman rankings and orders the condition effects.

In cases where differences between conditions were determined to be statistically significant using the Friedman test, multiple comparisons were then conducted. Appendix B contains the functions written in the S-Plus programming language used to implement the nonparametric tests.

1. Friedman Test

The following two assumptions must be satisfied to justify use of the Friedman test: 1) the subject responses are mutually independent 2) responses are on an ordinal scale. Conover (1999) refers to the subjects as blocks, and this convention will also be used in this thesis. The operational environments (sea, port, shore duty and leave status) are regarded as a set of repeated treatments applied to each subject. The Friedman test was executed in S-Plus. Each question was evaluated separately using the MyFriedman() function. In the event that subjects failed to respond to a particular condition (either lack of response in that condition or an error of omission), that subject was removed from further analysis in that question only.

Presented below is the derivation of the statistic used in the Friedman test. Each question is tested to assess if at least one condition differs from another condition. Because of the strong likelihood that ties would be present in the data, the statistic formula presented accounts for this likelihood in each treatment (i) and block (b) and provides for the appropriate adjustment along with a correction factor. The approximate chi-squared distribution, degrees of freedom, df $\{\chi^2_{(k-1)}\}$, and a p-value are returned from the S-Plus function friedman.test(). The adjustment factor represents the sums of the squares of the ranks and average ranks. The correction factor adjusts for the discrete nature of the data.

Adjustment factor: $A_1 = \sum\sum[R(X_{ij})]^2$ i: 1,…,k and j: 1,…,b

Correction factor: $C_1 = bk(k+1)^2/4$

Statistic: $T_1 = \dfrac{(k-1)\sum(R_j - b(k+1)/2)}{A_1 - C_1}$ j: 1,…,k

2. Page Test for Ordered Alternatives

Like the Friedman test, the Page Test also states in its null hypothesis that there is no difference between conditions. The alternative hypothesis specifies some ordering of the treatment effects. This test is well suited for this survey data in that not only are the conditions mutually exclusive, but there is some expectation that the condition ranks can be ordered. The conditions are numbered from one to four. If the expected condition equals one, then the quality and quantity of sleep obtained is less at sea and takes on the following form:

At sea < In Port < Shore Duty < On Leave

The Page Test is not available in S-Plus so the MyPage() function was created to obtain the required statistics. The GroupRank() function was created to take the output from the MyFriedman() function and to return the ranks of repeated measure within each subject for each of the k=4 conditions and the condition sums of rank. This output serves as the argument to the MyPage() function that calculates the statistics outlined in Conover (1999, p. 380). The function return includes the T_4 and T_5 statistics.

Statistics: $T_4 = \sum j R_j \quad j: 1,\ldots,k$

$$T_5 = \frac{T_4 - bk(k+1)^2/4}{[b(k^3 - k)^2/144(k - 1)]^{1/2}}$$

3. Multiple Comparisons

The null hypotheses state that there were no differences between conditions. The alternative hypotheses stated that at least one of the conditions differs from at least one other condition. The results from the Friedman test reported very small p-values. It was determined that at least one of the conditions was significantly different from at least one other condition. The multiple comparisons test is designed to compare conditions only in

the event that the Friedman test resulted in the rejection of the null hypothesis. The multiple comparison tests looked at each possible pairing of conditions and determined if these individual differences between conditions was indeed significant. The first formulation uses the t distribution for small sample sizes. Because our samples sizes were large (greater than 93 for all questions), the formulation was modified to use the normal quantiles and qnorm() feature of S-Plus.

Statistic: $| R_j - R_i | > t_{1-\alpha/2} \quad [2(bA_1 - \sum Rj^2 / (b-1)(k-1)]^{1/2}$

Modified statistic: $| R_j - R_i | > z_{1-\alpha/2} \quad [2(bA_1 - \sum Rj^2 / (b-1)(k-1)]^{1/2}$

D. STATISTICAL RESULTS

Both the Friedman Test and the Page Test for ordered alternatives indicate significant differences between operational conditions for each of the survey questions. The selected questions reported p-values < .001 with the Friedman test and p-values < .01 for the Page test.

Question 17b is similar to question 30 since both focus on sleep disruptions either in hours or by frequency of occurrence. Assuming that all subjects have normal sleeping habits and no sleep disorders, the instances of disturbances should not be different between conditions. Subjects may have made adjustments based on poor sleep conditions (e.g., other submariners moving about in the sleeping area, loudspeaker announcements or alarms) vice considering only the frequency of times awakened by normal or natural causes. The Page test returns a p-value of .0180 for question 18. The Friedman test and the Page test returned p-values of .0032 and .0109, respectively, for question 30. This question asks the subjects to identify the hours of sleep needed to function optimally. In the event that amount of sleep desired is the same regardless of operational environment; the null hypothesis would not be rejected. It is debatable if the number of hours of desired sleep should be the same. Submariners may adapt their reported preference for increased amounts of sleep needed to more closely resemble the actual sleep available in each environment.

E. SUMMARY

The main findings of this analysis show that there are differences in quality and quantity of sleep between operational conditions. Both the Friedman and Page tests show significant differences between total sleep and desired sleep to function. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions.

Finally, there is a positive correlation between the amounts of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep needed to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the 'at sea' condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

V. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

A. CONCLUSIONS

The results of this thesis conclude that there are differences in quality and quantity of sleep between operational environments. Abnormalities in sleep patterns may be attributed to the working conditions, specific type of platform of service (e.g. SSN, SSBN, shore duty, training environment), the time delay in self-reporting, military rating, personnel skill levels, technical expertise in each department, and manning levels. Existing practices of sleep management or sleep logistics can help supervisors accurately assess the fatigue levels of submariners. A concurrent shift in organizational culture can incorporate appropriate techniques to encourage submariners to use leisure time more effectively while also creating an environment where submariners can report feelings of fatigue to supervisors without the fear of reprisals.

B. RECOMMENDATIONS FOR FUTURE WORK

The results of the current survey analysis lend support to more detailed studies that can exact specific data elements useful for behavioral models and performance indicators. The statistically significant results and the positive correlation are indications that specific models could be developed. Using additional information gained from laboratory studies, when given the amount of total sleep, a model would then predict the response of desired sleep to function. Further use of predictive models would give supervisors a quantitative tool to identify submariners most likely to suffer performance degradation at various levels of operational readiness and monitor increasing fatigue levels.

While this survey asked subjects to report the amount of uninterrupted sleep, a revision might replace this with a request for the amount of interrupted sleep and the frequency of interruptions. The amount of uninterrupted sleep could then be deduced while providing the chain of command with valuable information on both the types and

times of interruptions that prevent submariners from obtaining sufficient rest. The use of sleep diaries, sleep logs and wrist-worn actigraphs provide future researchers with more objective means of validating subject responses.

Delayed Sleep Phase Syndrome (DSPS) is a newly reported disorder in which the circadian rhythm is no longer in cycle (deBeck, 1990). A person suffering from DSPS will be unable to sleep or awake at precise times. This leads to increased levels of sleepiness and affects one's ability to function in a normal working environment. The application to military professionals lies in the fact that most sufferers are adolescents or college age students because of their variability in sleep/wake cycles. The military environment traditionally recruits young sailors, of this age group, and typically assigns them to duties and tasks with greater variability in their work schedules. A future study might include a sleep analysis of members recommended for discharge due to tardiness or inability to show up at prescribed times.

A current research study at the Warfighter Countermeasures Laboratory, Brooks AFB is attempting to systematically evaluate submariners and the 18-hour day schedule and to assess its impact on human performance. Despite the satisfaction of this group of submariners with the predominant 18-hour watch schedule, serious attention must be given to the effect of fatigue on mission accomplishment. The simulated exercises performed in the typical sleep laboratory are designed to evaluate changes in human performance at various levels of sleep deprivation. As stated in Chapter II, this type of evaluation is superficial due to the laboratory environment. Specific review of task analyses and task requirements for each submarine rating would allow researchers the opportunity to identify the specific tasks most likely impacted by sleep loss.

A redesign of the NSMRL survey would allow future researchers to eliminate questions that do not directly pertain to fatigue. Nonparametric techniques were used in this thesis due to the categorical nature of data elements. The demographic questions in the survey could be changed to allow the subjects to give more specific information (e.g., age, years of service, amount of sleep, etc). For these questions, parametric techniques could then be used to report the average of the responses.

APPENDIX A. SELECTED TOOLS FOR MEASURING FATIGUE

ESS	Epworth Sleepiness Scale
MSLT	Multiple Sleep Latency Test
FFS	Fatigue Feelings Scale
SSQ	Stanford Sleepiness Questionnaire
SSS	Stanford Sleepiness Scale
MWT	Maintenance Wakefulness Test
NHRC PAB	Naval Health Research Center Performance Assessment Battery
RPD	Recognition Primed Decision Model

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APPENDIX B. S-PLUS FUNCTIONS

A. MyFriedman()

1. Commands

```
q17a <- c('TotSleep1', 'TotSleep2', 'TotSleep3', 'TotSleep4')

q17a.fried <- MyFriedman(X, q17a,1)
```

2. Function

```
> MyFriedman
function(X, grpvec, type)
{
# Created by Professor Robert A. Koyak 10 August 2001.
# Modified by LT Simonia Ridley Blassingame for application in NPS Thesis.
#
# This function accepts a matrix or data.frame and computes the friedman.test
# prescribed in S-Plus the test is performed upon a selected group of treatments
# (grpvec) with a certain number of factor levels:
# factor type 1 refers to the questions related to amount/length  of sleep
#      (11 factor levels)
# factor type 2 refers to the questions related to frequency of  events
#      (5 factor levels)
# Returned are the concatenated lists of Friedman Test (returns the data, Friedman # chi-
square, the degrees of freedom = (number of treatments - 1), the p-value for # a two sided
# hypothesis and the number of subjects (blocks).
        k <- length(grpvec)
        n <- dim(X)[1]
        nk <- n * k
        if(type == 1)
                resp <- c("4 or less", "4.5", "5", "5.5", "6", "6.5", "7", "7.5", "8", "8.5", "9
or more")
        if(type != 1)
                resp <- c("Never", "Rarely", "Sometimes", "Often", "Frequently",
"Always")
        x1 <- numeric(nk)
        x3 <- numeric(nk)
        x2 <- numeric(nk)
        ii <- 0
        for(j in 1:n) {
                use.subj <- T
                for(kk in 1:k) {
```

```
                ii <- ii + 1
                x1[ii] <- X$ID.[j]
                x2[ii] <- kk
                x3[ii] <- match(X[j, grpvec[kk]], resp)
                if(is.na(x3[ii]))
                        use.subj <- F
        }
        if(!use.subj)
                x3[(ii - k + 1):ii] <- NA
    }
    tt <- !is.na(x3)
    return(list(friedman.test(x3[tt], x2[tt], x1[tt]), ID = x1[tt], group = x2[tt], response
= x3[tt], beg.n = n, end.n =
        length(x1[tt])/k, gk = k))
}
```

3. Partial listing of results

```
q17a.fried
$"":

        Friedman rank sum test

data:  x3[tt] and x2[tt] and x1[tt]
Friedman chi-square = 151.9024, df = 3, p-value = 0
alternative hypothesis: two.sided

$ID:
 [1] 2047 2047 2047 2047 2062 2062 2062 2062   47   47   47   47 2011 2011 2011 2011

$group:
 [1] 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1

$response:
 [1]  8  8  8  8  8  5  1  9  6  7  6  9  1  4  7  9  5  3  1  9  3  9  9  9  3  5  7  9  1  1  1  1  5  7

$beg.n:
[1] 143

$end.n:
[1] 102

$gk:
[1] 4
```

B. GroupRank()

1. Commands

```
q17a.gr <- GroupRank(q17a.fried$response, q17a.fried$gk)
```

2. Function

```
> GroupRank
function(x, k)
{
# This function accepts vector x, of length n*k, where n = number of subjects and
# k = number of repeated measures.
#
# Returned is a vector of the same length as x containing ranks for each of the
# repeated measures within each subject, and a vector of length k containing sums of
 # ranks for each of the k treatments, over all subjects
#
        m <- length(x)
        n <- m/k
        y <- numeric(m)
        s <- numeric(k)
        ihi <- 0
        for(j in 1:n) {
                ilo <- ihi + 1
                ihi <- ihi + k
                y[ilo:ihi] <- rank(x[ilo:ihi])
        }
        for(j in 1:k)
                s[j] <- sum(y[seq(j, m - k + j, k)])
        Z <- list(y, s, n)
        names(Z) <- c("rank.assign", "sums", "blocks")
        return(Z)
}
```

3. Partial listing of results

```
> q17a.gr
$rank.assign:
[1] 2.5 2.5 2.5 2.5 3.0 2.0 1.0 4.0 1.5 3.0 1.5 4.0 1.0 2.0 3.0 4.0 3.0 2.0 1.0 4.0 1.0 3.0 3.0

$sums:
[1] 166.0 225.0 261.5 367.5

$blocks:
[1] 102
```

C. MyPage()

1. Commands

```
q17a.page <- MyPage(q17a.gr$sums, q17a.gr$blocks)
```

2. Function

```
> MyPage
function(x, b, exp)
{
# This function is designed to perform the Page Test for Ordered Alternatives.
# This function takes in the $sums from the GroupRank function.  The list is then
computes the value of the T4 and T5
# statistic as stated in Practical Nonparametric Statistics by W. J. Conover (1999).
# The null hypothesis test the expectation that the ranks for all conditions will be the
# same against the alternative hypothesis that will state there is no difference between the
# conditions.
# Page asserts that we number the ranks such that the lowest expected sum should
# correspond to the condition with the smallest rank.  If a 1 is entered for var, then the
# expectation is that the AtSea (condition 1) will be smaller than the other conditions.
# Otherwise, the expectation is that either the ShoreDuty (condition 3) or
# OnLeave (condition 4) will have the lowest rank.
# Note:  OnLeave (condition 4) is not applicable to all sections
        T4 <- 0
        T5 <- 0
        T5.num <- 0
        T5.den <- 0
        k <- length(x)
        r <- numeric(k)
        s <- numeric(k)
        part.sum <- numeric(k)
        if(exp > 1)
                r[1:k] <- 1:k
        s[1:k] <- x[k:1]
        part.sum[1:k] <- sum(s[1:k])
        if(exp == 1)
                r[1:k] <- 1:k
        s[1:k] <- x[1:k]
        part.sum[1:k] <- sum(s[1:k])
        T4 <- sum(r[1:k] * s[1:k])
        k <- length(x)
        T5.num <- T4 - ((b * k * (k + 1)^2)/4)
        T5.den <- ((b * (k^3 - k)^2)/(144 * (k - 1)))^(1/2)
        T5 <- T5.num/T5.den
```

```
        if(T5 > 0)
                p <- 1 - pnorm(T5)
        if(T5 < 0)
                p <- pnorm(T5)
        return(T4, T5, T5.num, T5.den, p value = p)
}
```

3. Partial listing of results

```
q17a.page <- MyPage(q17a.gr$sums, q17a.gr$blocks)

> q17a.page
$T4:
[1] 2870.5

$T5:
[1] 10.99306

$T5.num:
[1] 320.5

$T5.den:
[1] 29.15476

$pvalue:
[1] 0
```

D. MyComparison()

1. Commands

```
q17a.comp <- MyComparison(q17a.gr)
```

2. Function

```
> MyComparison
function(X)
{
# This function takes the arguments from GroupRanks and performs a multiple
comparison as outlined in Conover, pg. 371.
        b <- X$blocks
        k <- length(X$sums)
        A.1 <- 0
        C.1 <- 0
        j <- 1:k
        sums.sqrd <- numeric(k)
        total.iter <- sum(k - j)
        comp <- numeric(total.iter)
        comp[1:total.iter] <- 0
        df <- (b - 1) * (k - 1)
        A.1 <- sum((X$rank.assign)^2)
        C.1 <- (b * k * (k + 1)^2)/4
        sums.sqrd[1:k] <- (X$sums[1:k])^2
        total.sums.sqrd <- sum(sums.sqrd[1:k])
        ti <- 1
        for(ii in 1:k - 1) {
                if(ii == 1)
                        ti <- 1
                if(ii == 2)
                        ti <- 4
                if(ii == 3)
                        ti <- 6
                for(jj in ii + 1:4) {
                        comp[ti] <- abs(X$sums[ii] - X$sums[jj])
                        ti <- ti + 1
                }
        }
        formula <- sqrt((2 * (b * A.1 - total.sums.sqrd))/df)
        extra <- !is.na(comp)
        return(list(A = A.1, C = C.1, sums.sqrd = sums.sqrd, total.sums.sqrd =
total.sums.sqrd, comparisons = comp[extra],
                total.comparisons = total.iter, df = df, MyComp.Output = formula))
}
```

3. Partial listing of results

```
> q17a.comp
$A:
[1] 2975

$C:
[1] 2550

$sums.sqrd:
[1]  27556.00  50625.00  68382.25 135056.25

$total.sums.sqrd:
[1] 281619.5

$comparisons:
[1]  59.0  95.5 201.5  36.5 142.5 106.0

$total.comparisons:
[1] 6

$df:
[1] 303

$MyComp.Output:
[1] 12.00399
```

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APPENDIX C. DESCRIPTIVE TABLES

	At Sea	In Port	Shore Duty	On Leave
4 or less	14	5	9	2
4.5	12	3	0	0
5	27	19	6	1
5.5	12	11	3	2
6	37	30	18	6
6.5	12	13	5	2
7	10	28	20	23
7.5	4	7	15	10
8	10	20	25	54
8.5	2	1	0	8
9 or more	2	4	2	30
Total	**142**	**141**	**103**	**138**

Table C1. Reported Hours Of Total Sleep (Question 17a)

	At Sea	In Port	Shore Duty	On Leave
4 or less	41	13	9	4
4.5	18	7	4	3
5	26	22	9	8
5.5	9	3	2	3
6	17	28	16	7
6.5	6	4	2	2
7	3	21	14	16
7.5	1	7	10	8
8	10	17	21	44
8.5	2	2	1	3
9 or more	8	14	6	35
Total	**141**	**138**	**94**	**133**

Table C2. Reported Hours Of Uninterrupted Sleep (Question 17b)

	At Sea	In Port	Shore Duty	On Leave
4 or less	4	0	2	3
4.5	2	4	1	2
5	19	13	10	12
5.5	4	2	1	2
6	41	36	27	36
6.5	9	6	1	3
7	25	30	24	25
7.5	7	6	5	7
8	28	38	27	41
8.5	2	2	2	2
9 or more	1	2	1	4
Total	**142**	**139**	**101**	**137**

Table C3. Report Amounts Of Desired Sleep (Question 18)

APPENDIX D. BAR CHARTS

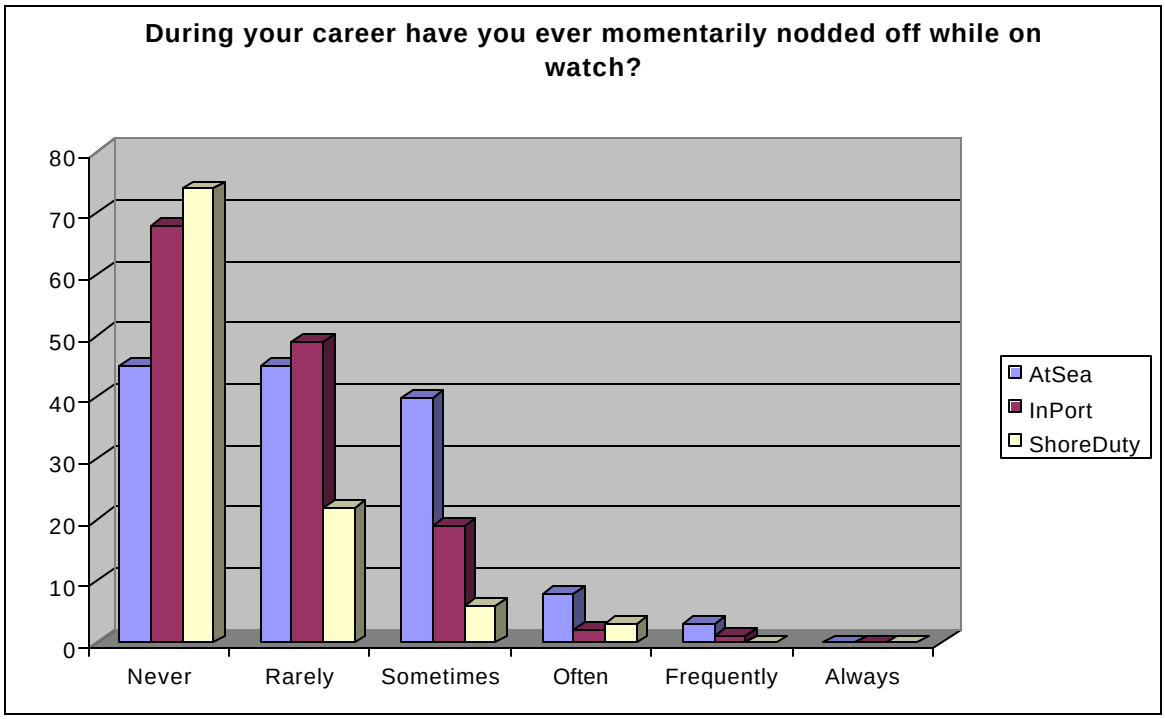

Figure D1. Question 19a (Refer to Appendix F for complete survey)

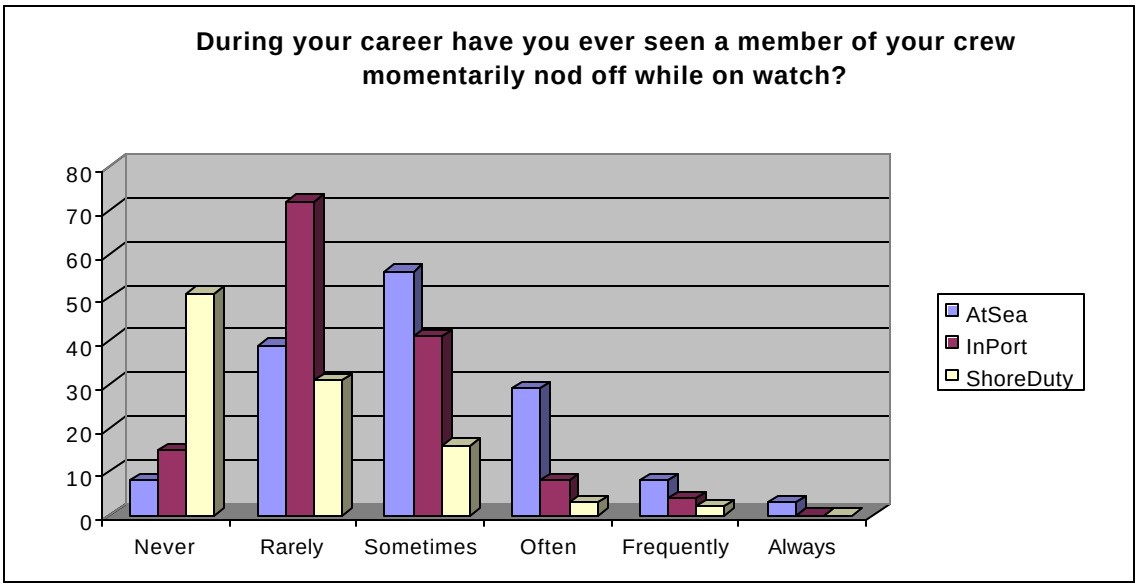

Figure D2. Question 19b (Refer to Appendix F for complete survey)

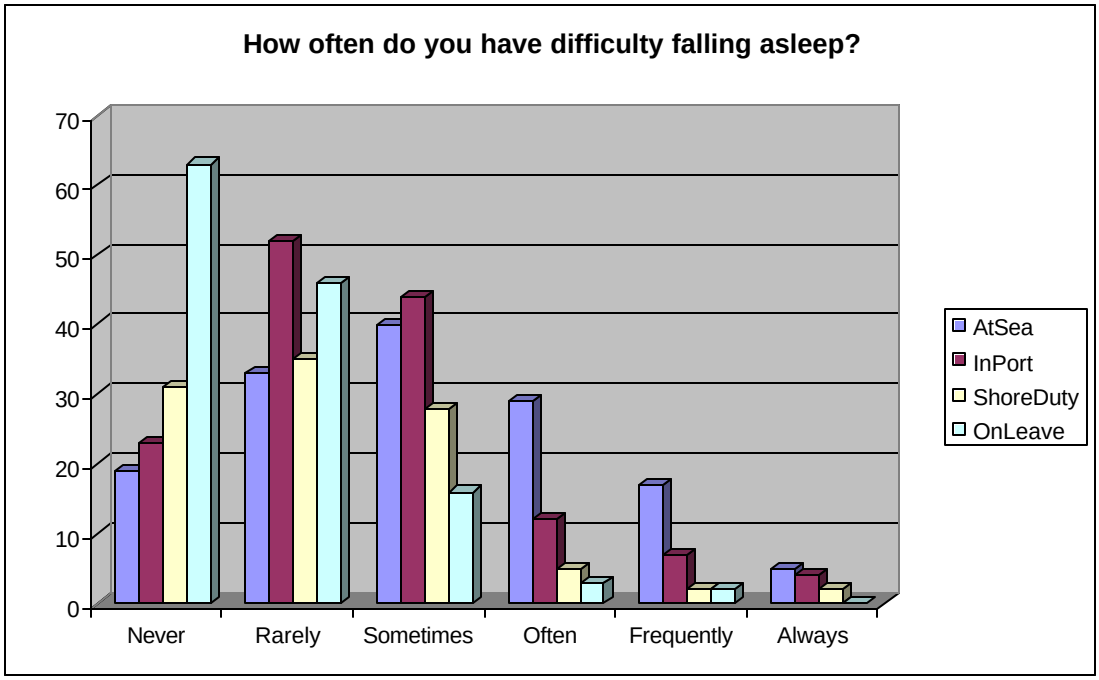

Figure D3. Question 20 (Refer to Appendix F for complete survey)

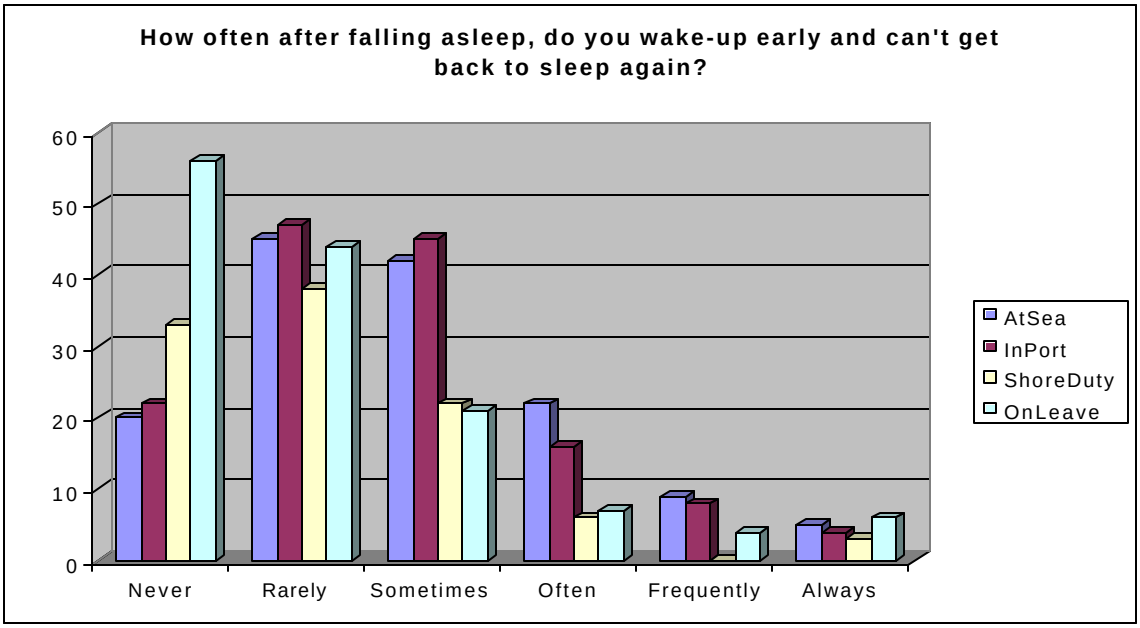

Figure D4. Question 21 (Refer to Appendix F for complete survey)

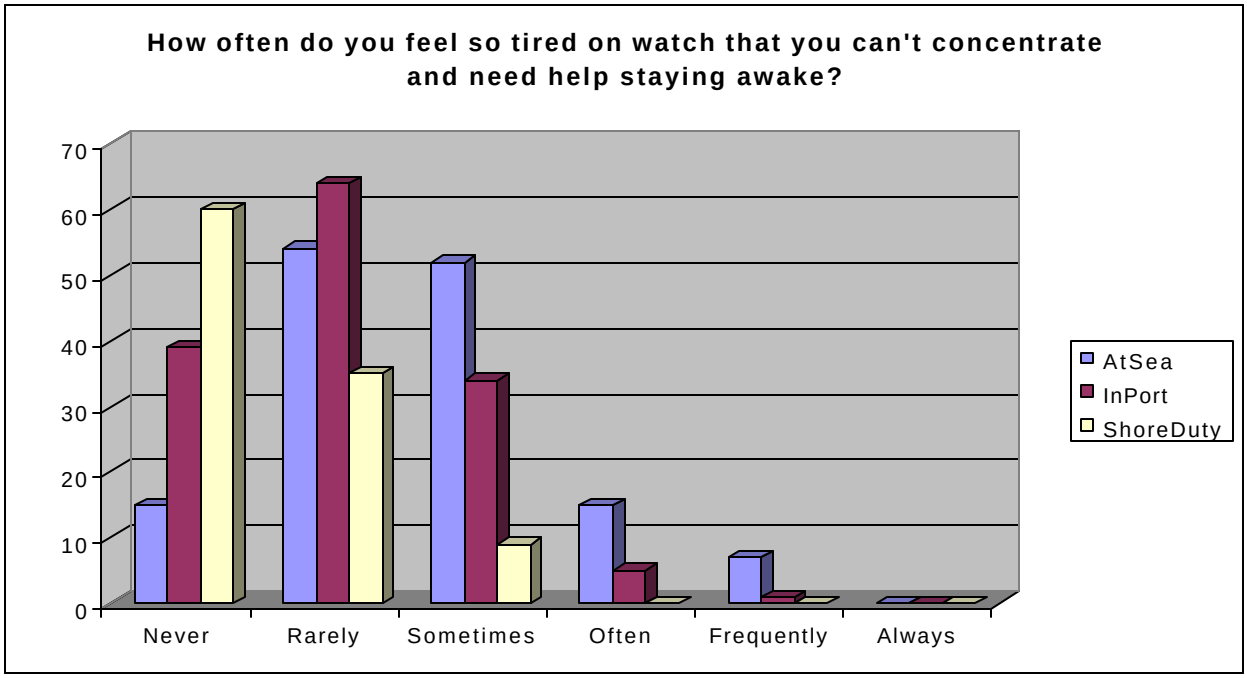

Figure D5. Question 22 (Refer to Appendix F for complete survey)

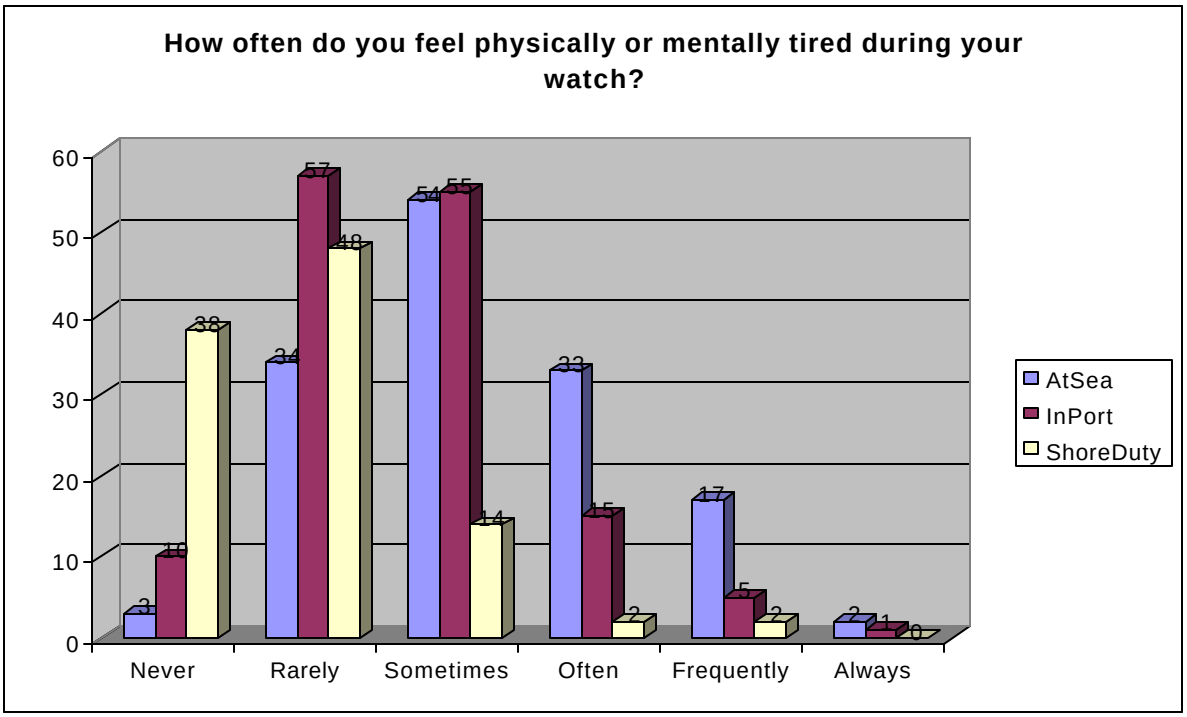

Figure D6. Question 23 (Refer to Appendix F for complete survey)

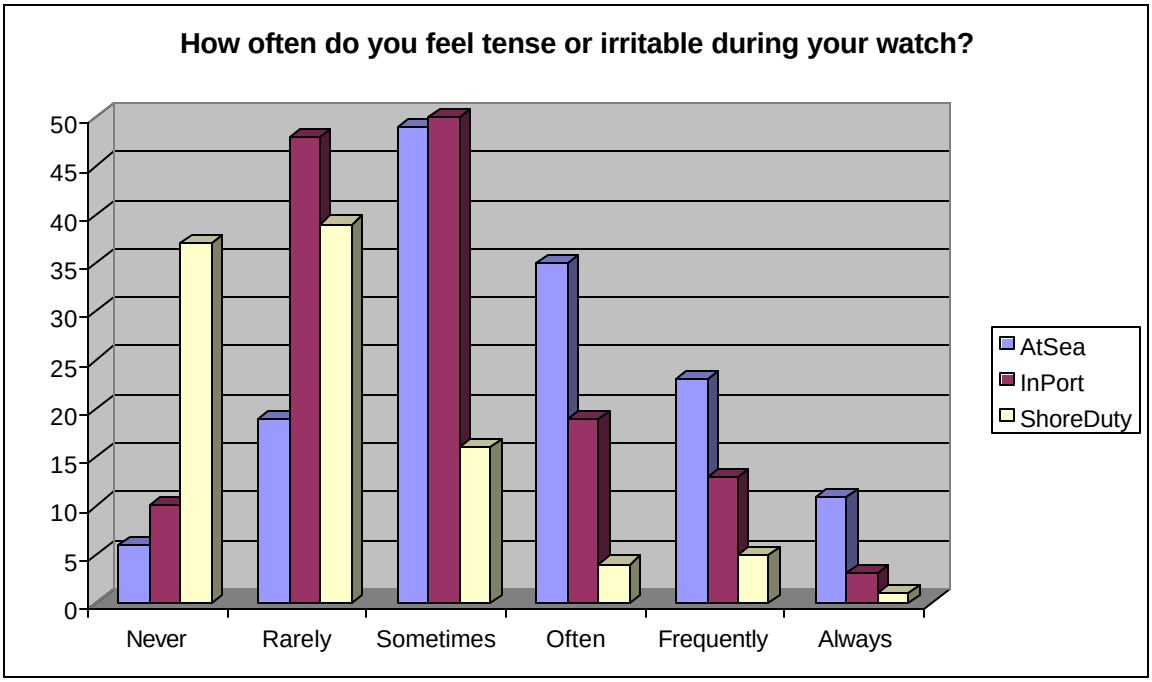

Figure D7. Question 24 (Refer to Appendix F for complete survey)

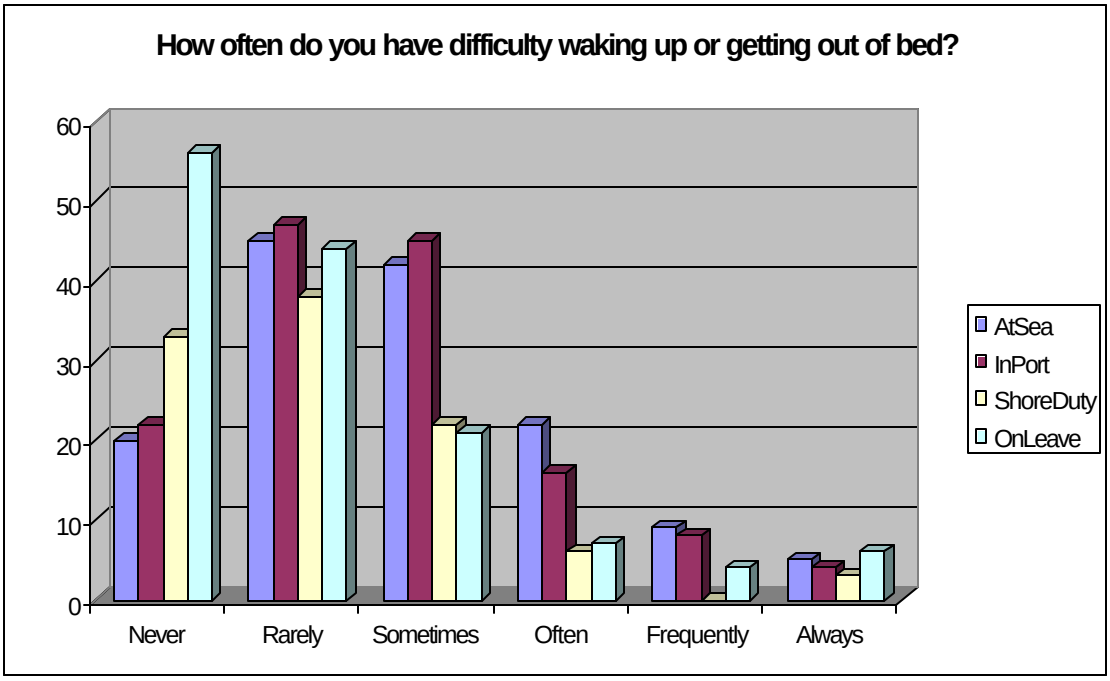

Figure D8. Question 25 (Refer to Appendix F for complete survey)

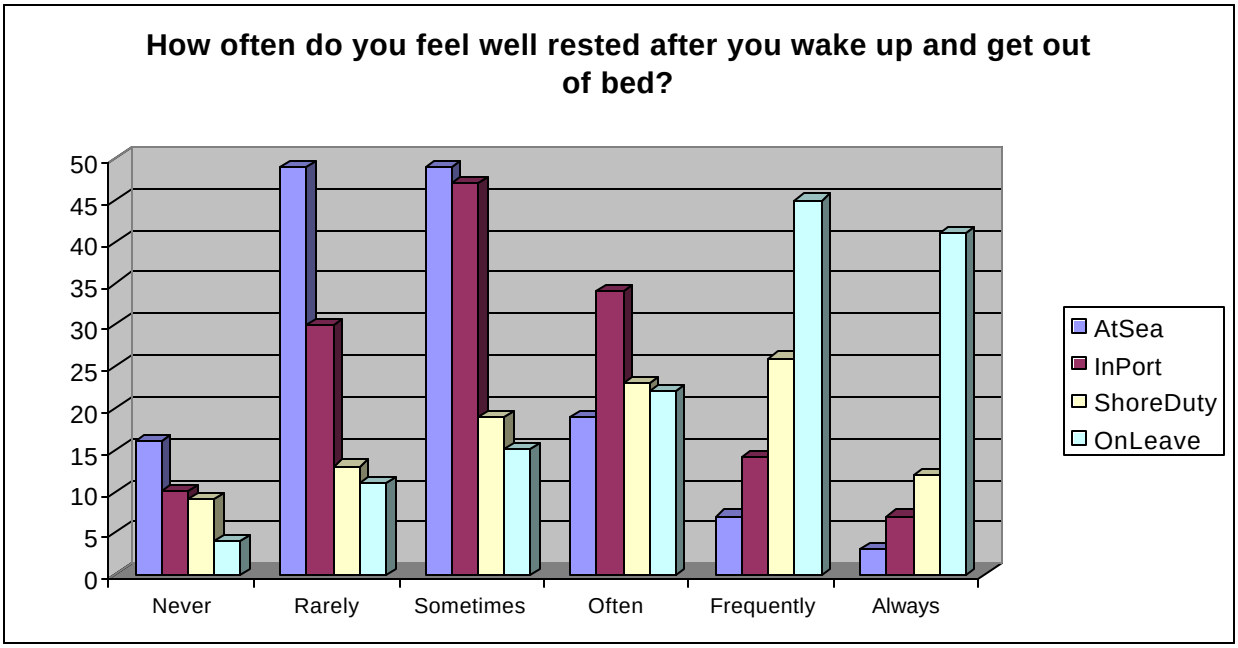

Figure D9. Question 26 (Refer to Appendix F for complete survey)

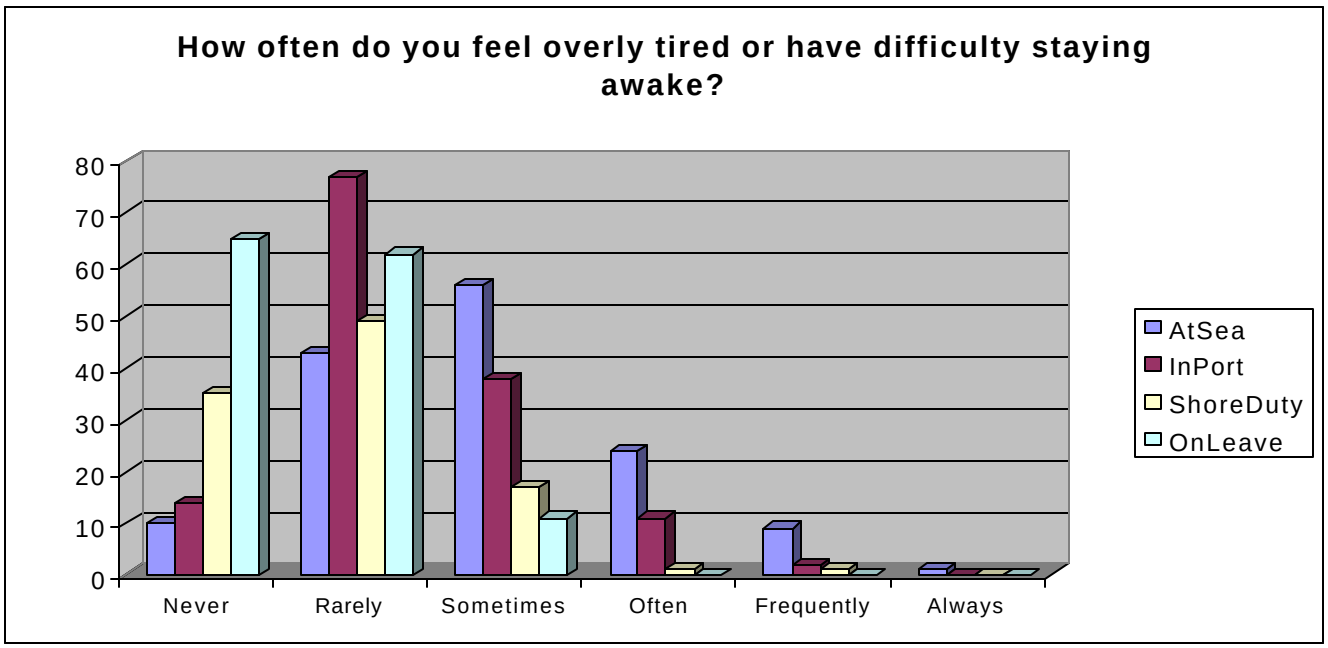

Figure D10. Question 27 (Refer to Appendix F for complete survey)

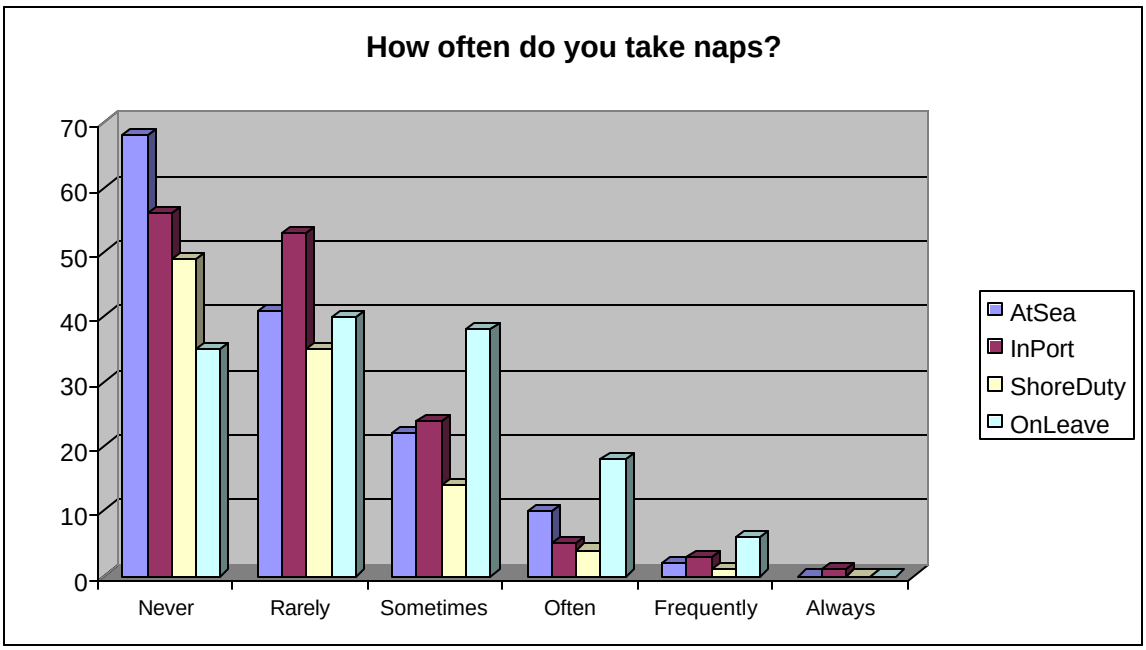

Figure D11. Question 28 (Refer to Appendix F for complete survey)

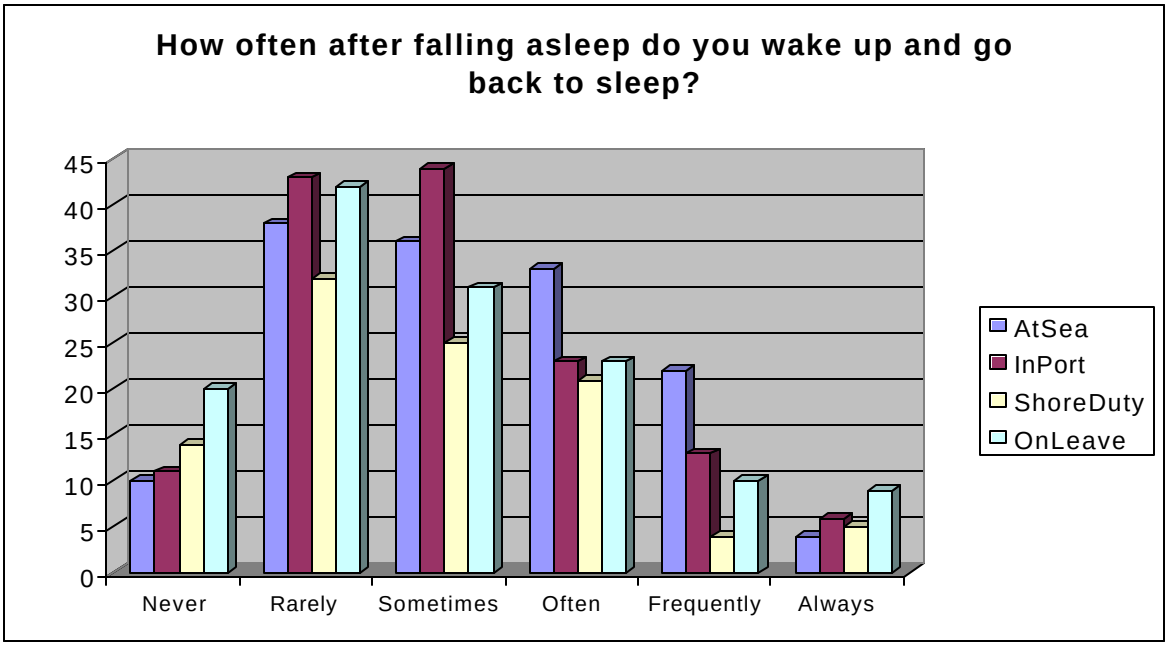

Figure D12. Question 30 (Refer to Appendix F for complete survey)

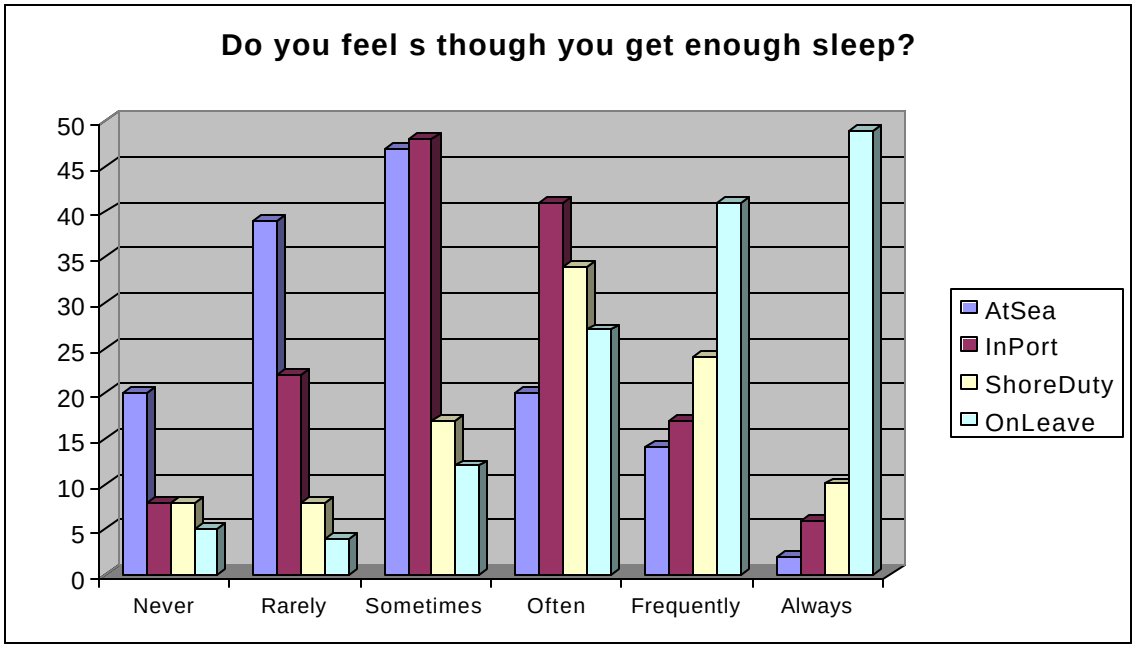

Figure D13. Question 31 (Refer to Appendix F for complete survey)

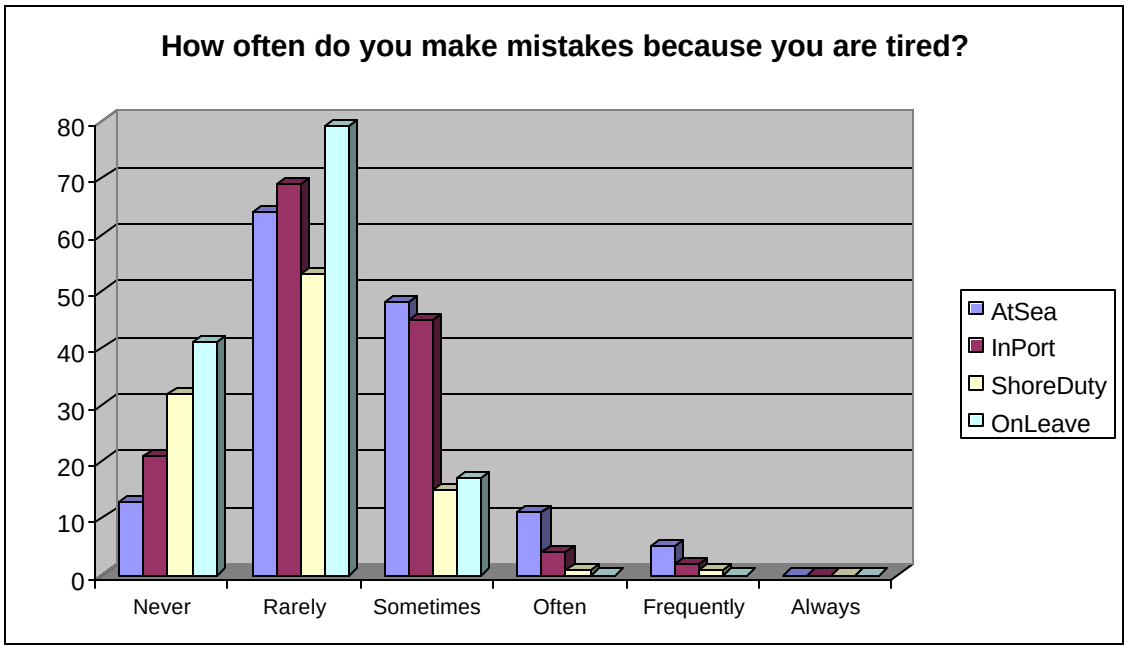

Figure D14. Question 33 (Refer to Appendix F for complete survey)

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APPENDIX E. BARPLOTS

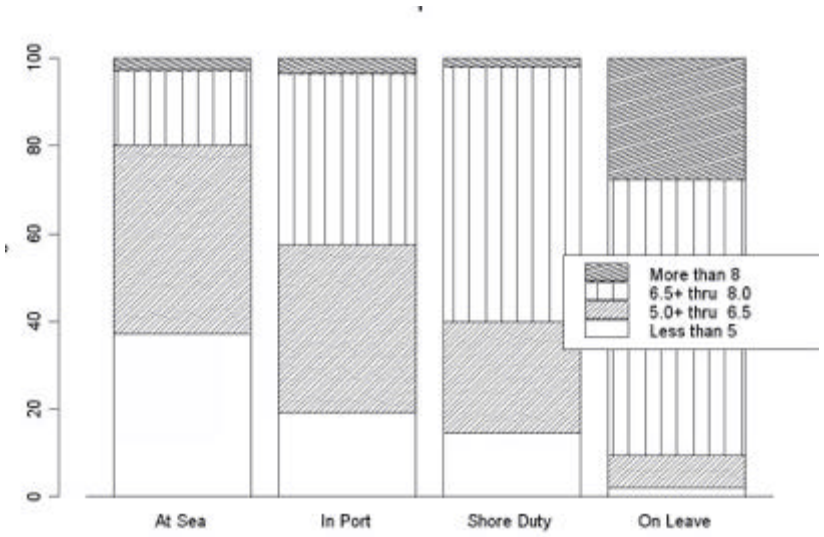

Figure E1. Question 17a (Refer to Appendix F for survey questions)

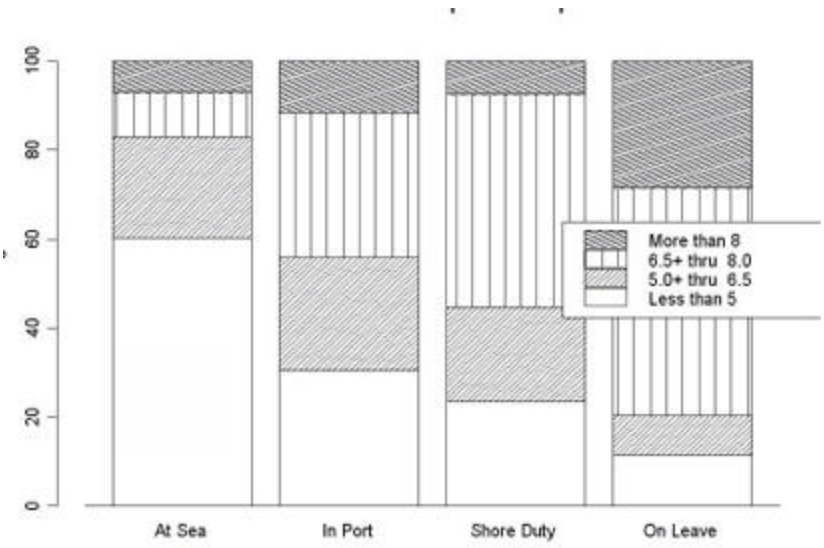

Figure E2. Question 17b (Refer to Appendix F for survey questions)

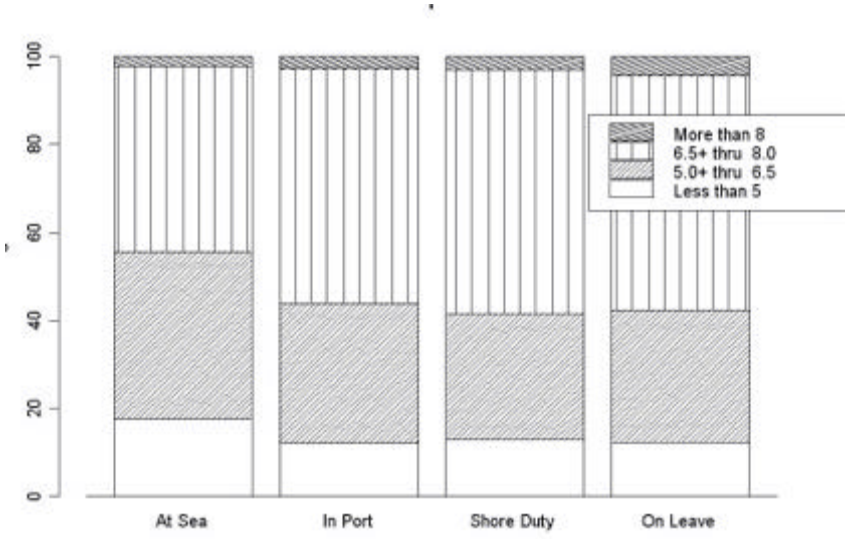

Figure E3. Question 18 (Refer to Appendix F for survey questions)

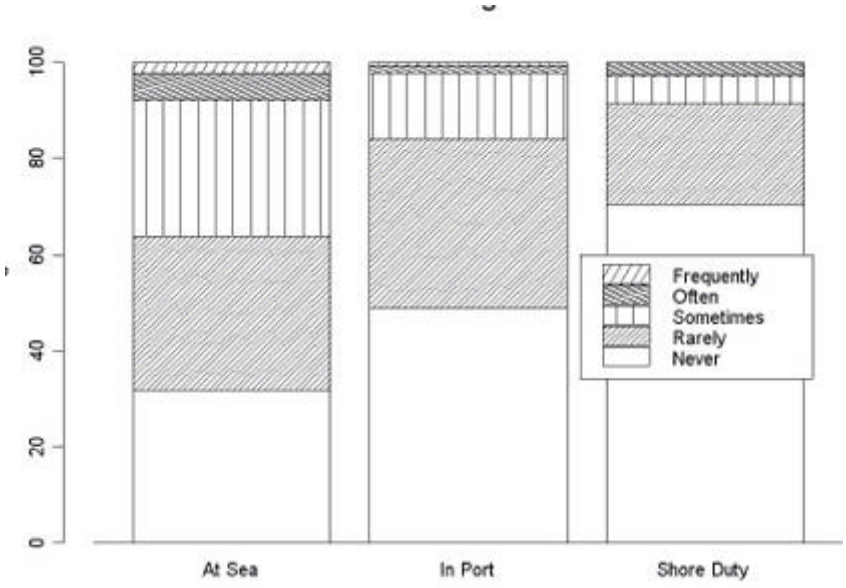

Figure E4. Question 19a (Refer to Appendix F for survey questions)

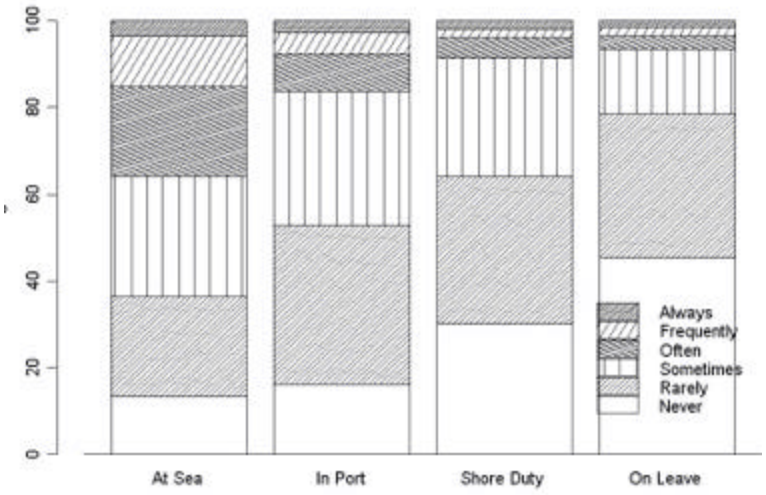

Figure E5. Question 19b (Refer to Appendix F for survey questions)

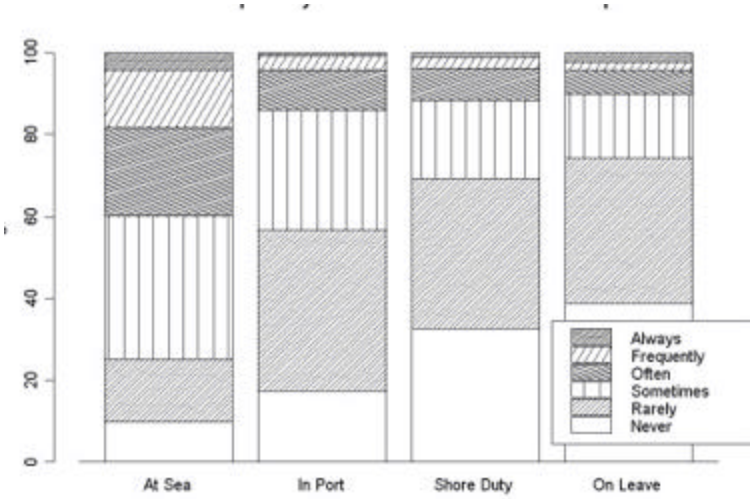

Figure E6. Question 20 (Refer to Appendix F for survey questions)

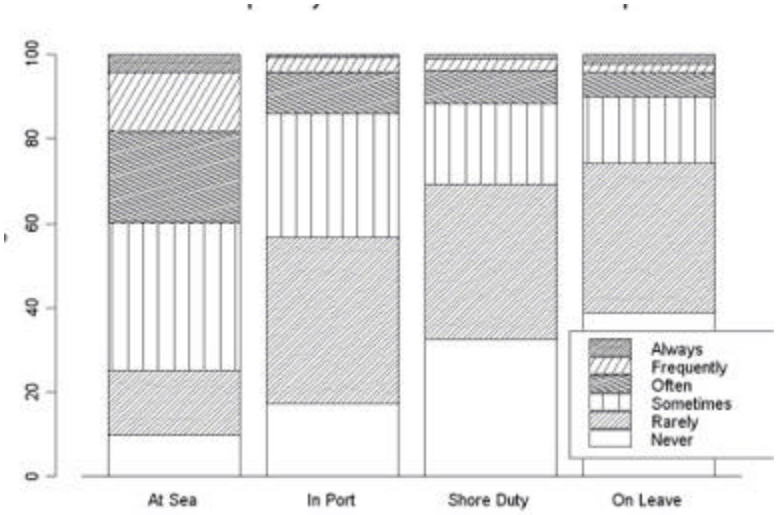

Figure E7. Question 21 (Refer to Appendix F for survey questions)

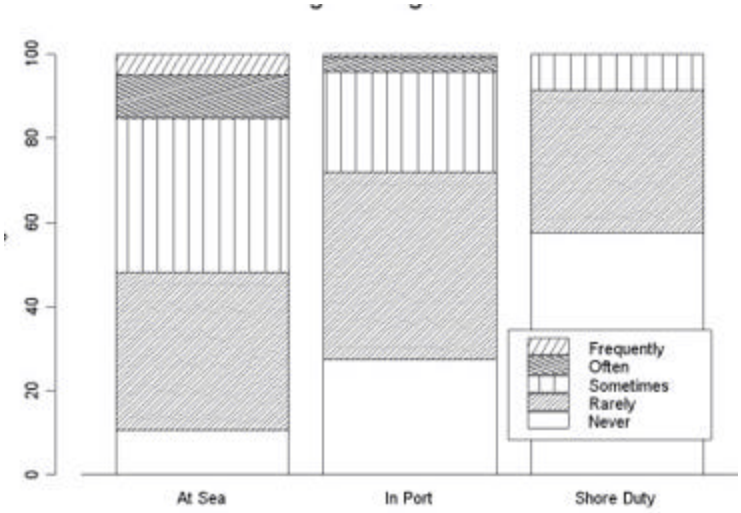

Figure E8. Question 22 (Refer to Appendix F for survey questions)

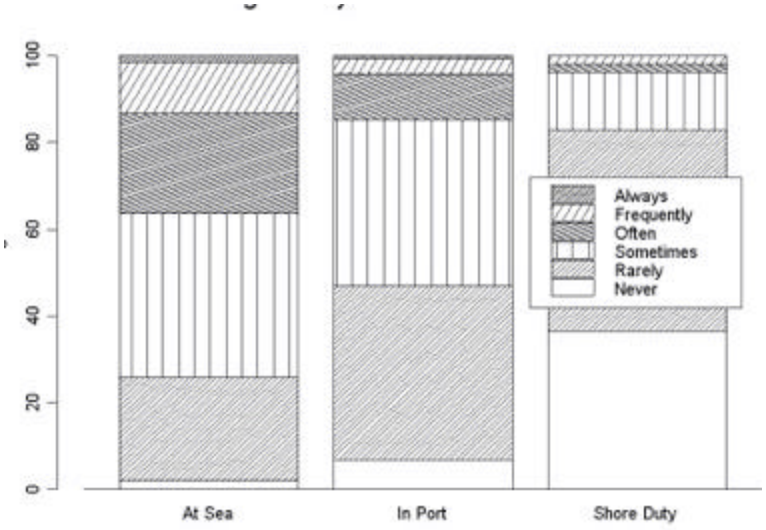

Figure E9. Question 23 (Refer to Appendix F for survey questions)

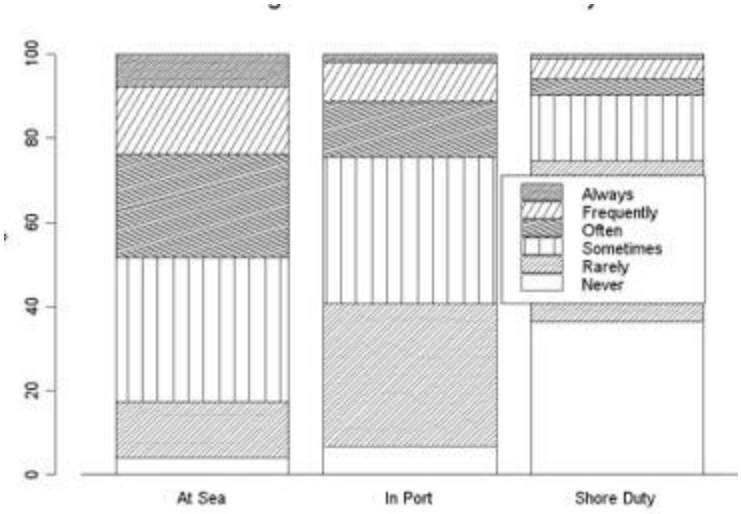

Figure E10. Question 24 (Refer to Appendix F for survey questions)

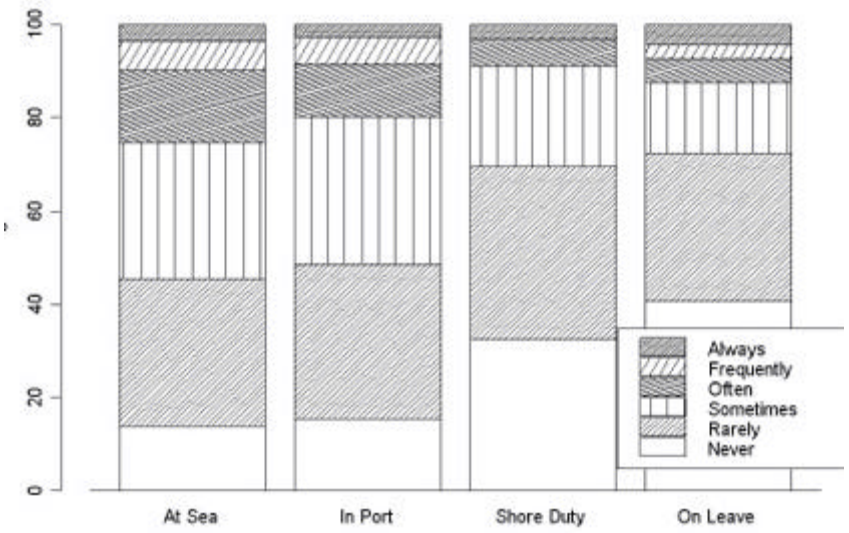

Figure E11. Question 25 (Refer to Appendix F for survey questions)

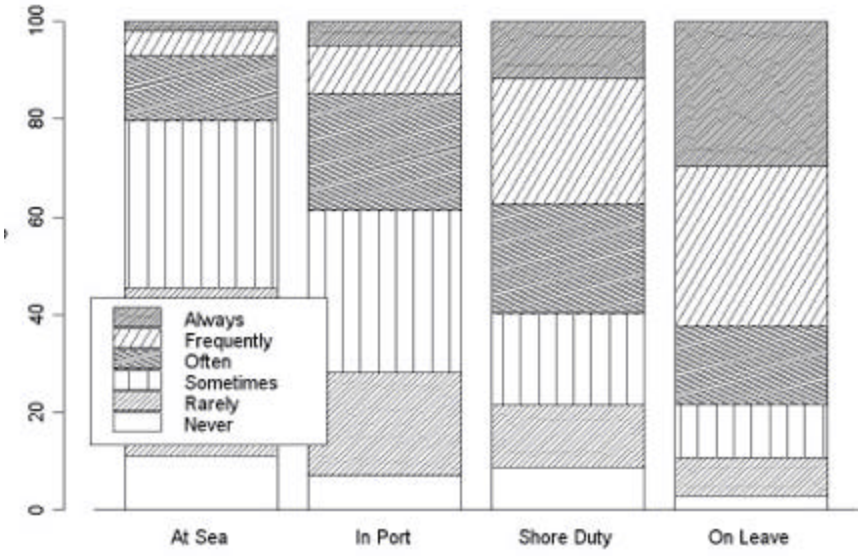

Figure E12. Question 26 (Refer to Appendix F for survey questions)

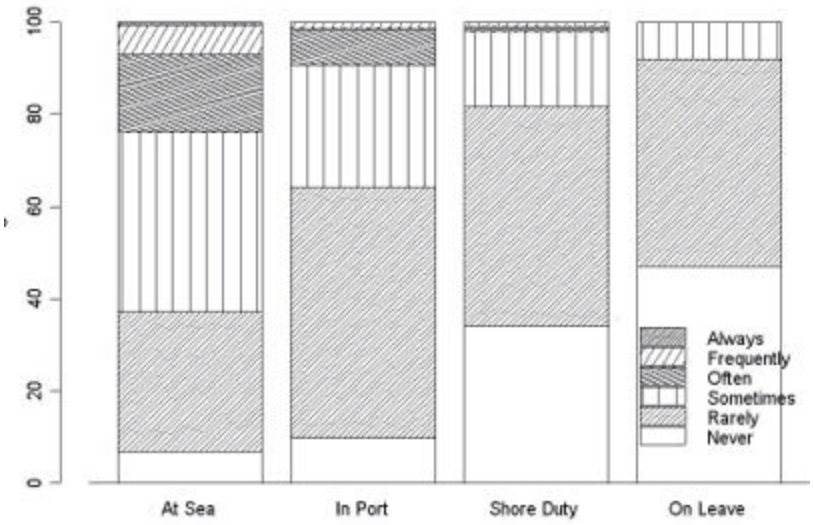

Figure E13. Question 27 (Refer to Appendix F for survey questions)

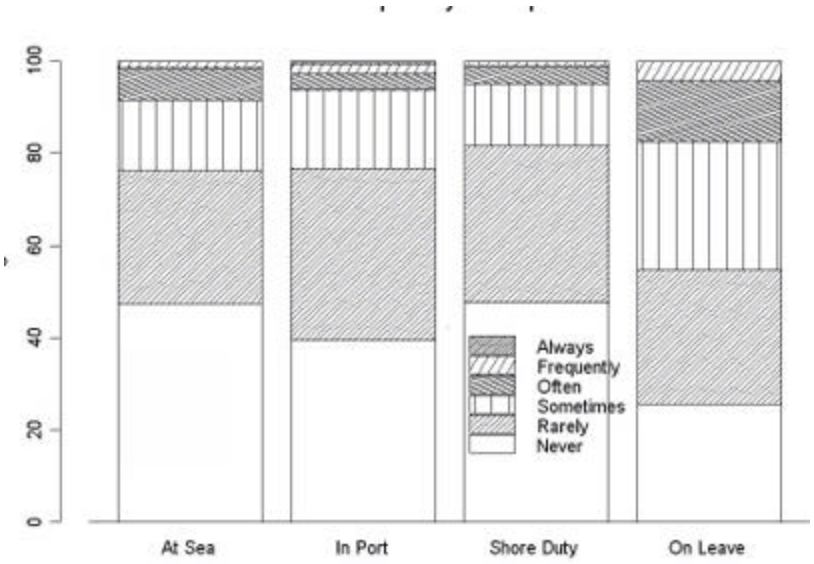

Figure E14. Question 28 (Refer to Appendix F for survey questions)

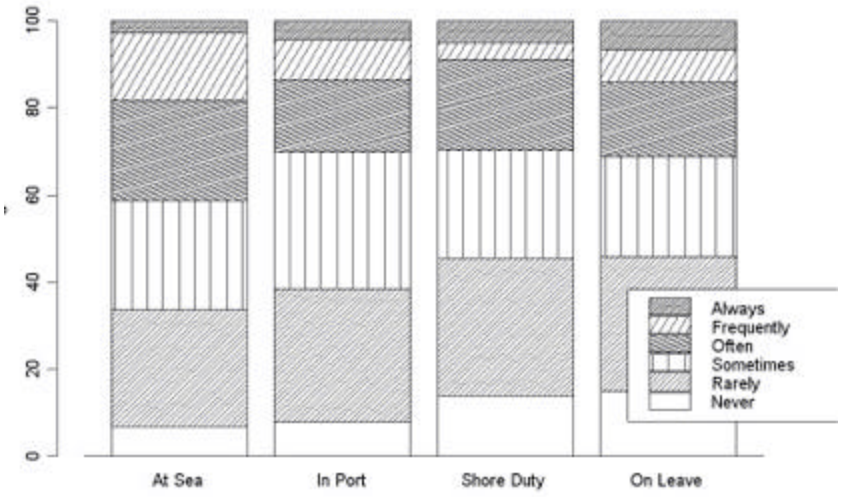

Figure E15. Question 30 (Refer to Appendix F for survey questions)

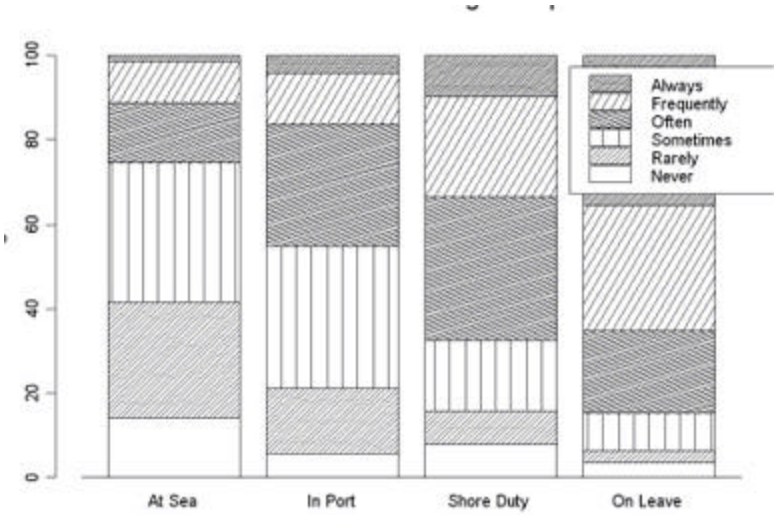

Figure E16. Question 31 (Refer to Appendix F for survey questions)

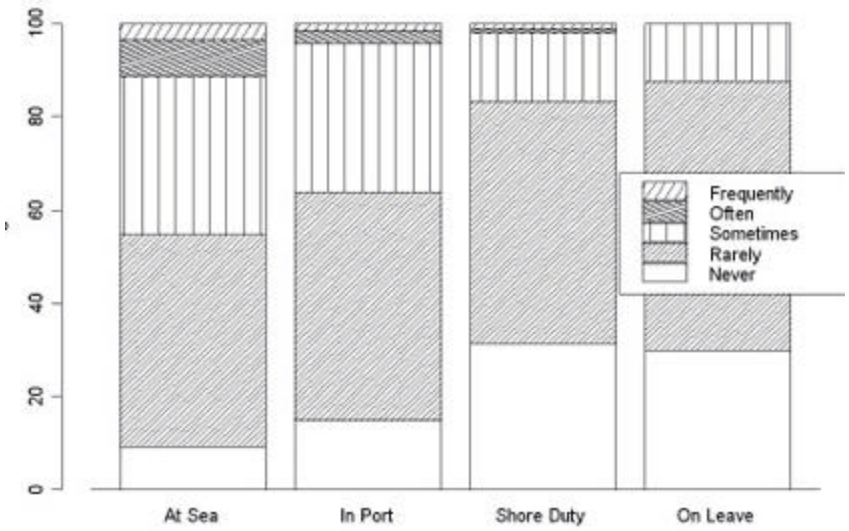

Figure E17. Question 33 (Refer to Appendix F for survey questions)

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APPENDIX F. NSMRL SUBMARINE WATCHSTANDING SURVEY

PLEASE MAKE HEAVY MARKS TO FILL THE CIRCLE COMPLETELY

BACKGROUND: **Current duty station: SSN ○ ○ SSBN**

1) Your age (Years)

17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-35	36-40	Older
○	○	○	○	○	○	○	○	○	○

2) While <u>on shore</u> do you live with any children under age 5? Yes ○ ○ No

3) What is your rank ?

○	○	○	○	○	○
E1 -E3	E4-E6	E7-E9	01-O2	03-O4	05-O6

4) What is your rate?

Seaman	EM	ET	FT	FTB	HM	MM	MT	MS	SK	STS	TM	YN	Other/NA
○	○	○	○	○	○	○	○	○	○	○	○	○	○

5) Are you submarine qualified? Yes ○ ○ No Nuclear designator? Yes ○ ○ No

6) What is your watch schedule <u>at sea (hours)?</u> <u>In port (days)?</u>

○	**6 hours on/6 off**	○	**1 day in 2**
○	**6 hours on/12 off**	○	**1 day in 3**
○	**12 hours on/12 off**	○	**1 day in 4**
○	**Other _____**	○	**Other _____**

7) During your time in the navy how many years have you served on the following:

	0	1	2	3	4	5	6	7	8	9	10	More
<u>SSN</u>	○	○	○	○	○	○	○	○	○	○	○	○
<u>SSBN</u>	○	○	○	○	○	○	○	○	○	○	○	○
<u>Shore Duty</u>	○	○	○	○	○	○	○	○	○	○	○	○

8) How many hours (per 24 hours) do you spend on watch, training and drilling?

	0	1-4	5 -8	9-10	11-12	13	14	15	16	17	More
<u>At Sea</u>	○	○	○	○	○	○	○	○	○	○	○
<u>In port</u>	○	○	○	○	○	○	○	○	○	○	○
Shore Duty	○	○	○	○	○	○	○	○	○	○	○

9) a. How many cups/cans/glasses of caffeinated coffee do you typically drink per 24 hours?

	0	1	2	3	4	5	6	7	8	9	More
At Sea	○	○	○	○	○	○	○	○	○	○	○
In port	○	○	○	○	○	○	○	○	○	○	○
Shore Duty	○	○	○	○	○	○	○	○	○	○	○
On Leave	○	○	○	○	○	○	○	○	○	○	○

b. How many cups/cans/glasses of caffeinated soda do you typically drink per 24 hours?

	0	1	2	3	4	5	6	7	8	9	More
At Sea	○	○	○	○	○	○	○	○	○	○	○
In port	○	○	○	○	○	○	○	○	○	○	○
Shore Duty	○	○	○	○	○	○	○	○	○	○	○
On Leave	○	○	○	○	○	○	○	○	○	○	○

10) Are you currently taking any prescription or over-the-counter medication?

Yes ○ ○ No

If Yes, which of the following?

Painkiller	Sleeping pill	Tranquilizer	Stimulant	Antihistamine	Vitamin	Other
○	○	○	○	○	○	○

11) Do you have another job while on shore for additional income? Yes ○ ○ No

12) During the past 30 days, on how many days did you smoke cigarettes?

0 days	1 or 2	3 to 5	6 to 9	10 to 19	20 to 29	All 30 days
○	○	○	○	○	○	○

a. On days you smoke cigarettes, how many cigarettes did you smoke per day?

	Did not smoke cigarettes	Less than 1	1	2 to 5	6 to 10	11 to 20	More than 20 a day
At Sea	○	○	○	○	○	○	○
In port	○	○	○	○	○	○	○
Shore Duty	○	○	○	○	○	○	○
On Leave	○	○	○	○	○	○	○

b. If you smoke, did you start smoking before joining the Navy? Yes ○ ○ No

14) a. During the past 30 days, on how many days did you use chewing tobacco or snuff, such as Redman, Levi Garrett, Beechnut, Skoal or Copenhagen?

0 days	1 or 2	3 to 5	6 to 9	10 to 19	20 to 29	All 30 days
○	○	○	○	○	○	○

b. If you chew or dip, did you start before joining the Navy? Yes ○ ○ No

15) During the past 30 days, on how many days did you smoke cigars, cigarillos, or little cigars?

0 days	1 or 2	3 to 5	6 to 9	10 to 19	20 to 29	All 30 days
○	○	○	○	○	○	○

16) Have you ever served on a submarine where a member was formally disciplined (NJP, court martial) for sleeping on watch? Yes ○ ○ No

SLEEP:

17) a. How many hours <u>Total</u> <u>Sleep</u> do you usually get per 24 hours when:

	HOURS										
	4 or less	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9 or More
<u>At Sea</u>	○	○	○	○	○	○	○	○	○	○	○
<u>In port</u>	○	○	○	○	○	○	○	○	○	○	○
<u>Shore Duty</u>	○	○	○	○	○	○	○	○	○	○	○
<u>On Leave</u>	○	○	○	○	○	○	○	○	○	○	○

b. On average, what is the longest period (in hours) of <u>Uninterrupted</u> <u>Sleep</u> you get per 24 hours when:

	HOURS										
	4 or less	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9 or More
<u>At Sea</u>	○	○	○	○	○	○	○	○	○	○	○
<u>In port</u>	○	○	○	○	○	○	○	○	○	○	○
<u>Shore Duty</u>	○	○	○	○	○	○	○	○	○	○	○
<u>On Leave</u>	○	○	○	○	○	○	○	○	○	○	○

18) How many hours of sleep, per 24 hours, do you think you need to function at your best?

	HOURS										
	4 or less	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9 or More**
At Sea	○	○	○	○	○	○	○	○	○	○	○
In port	○	○	○	○	○	○	○	○	○	○	○
Shore Duty	○	○	○	○	○	○	○	○	○	○	○
On Leave	○	○	○	○	○	○	○	○	○	○	○

Key for questions 19-33 For each question please fill in the bubble for the appropriate response.

Never - once or twice in lifetime	**Often - once or twice a week**
Rarely - once or twice a year	**Frequently - three or four times a week**
Sometimes - once or twice a month	**Always - five times a week or more**

19) a. During your career have you ever momentarily nodded off while on watch?

	Never	**Rarely**	**Sometimes**	**Often**	**Frequently**	**Always**
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○

b. During your career have you ever seen a member of your crew momentarily nod off while on watch?

	Never	**Rarely**	**Sometimes**	**Often**	**Frequently**	**Always**
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○

20) How often do you have difficulty falling asleep?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

21) How often after falling asleep, do you wake-up early and can't get back to sleep again?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

22) How often do you feel so tired on watch that you can't concentrate and need help staying awake?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

23) How often do you feel physically or mentally tired during your watch?

At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○

24) How often do you feel tense or irritable during your watch?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○

25) How often do you have difficulty waking up or getting out of bed?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

26) How often do you feel well rested after you wake up and get out of bed?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

27) How often do you feel overly tired or have difficulty staying awake ?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

28) How often do you take naps?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

29) How often do you have restless sleep or disturbing dreams or nightmares?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

30) How often after falling asleep do you wake up and go back to sleep?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

31) Do you feel as though you get enough sleep?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

32) How often do you suffer from headaches?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

33) How often do you make mistakes because you are tired?

	Never	Rarely	Sometimes	Often	Frequently	Always
At Sea	○	○	○	○	○	○
In port	○	○	○	○	○	○
Shore duty	○	○	○	○	○	○
On Leave	○	○	○	○	○	○

34) Are you satisfied with the current watchstanding routine at sea?

Yes ○ ○ **No**

What would you like to change about the current watchstanding routine at sea ?

_____

_____

What do you like about the current watchstanding routine at sea ?

_____

_____

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APPENDIX G. DATA RESULTS

Survey	n		factor	Exp	Rank Sums				Friedman Test			Page Test		
Question	beg.n	end.n	level	cond	AtSea(1)	InPort(2)	ShoreDuty(3)	Leave(4)	chi-square	df	*pvalue*	T4	T5	*pvalue*
17a	143	102	1	1	166.0	225.0	261.5	367.5	151.90	3	***0.0000***	2870.5	10.9931	***0.0000***
17b	143	93	1	1	141.5	228.0	246.0	314.5	132.43	3	***0.0000***	2593.5	9.6448	***0.0000***
18	143	100	1	1	224.0	256.0	255.5	264.5	27.61	3	***0.0000***	2560.5	2.0958	***0.0180***
19a	143	104	2	3	246.0	204.0	174.0	NA	52.32	2	***0.0000***	1176	-4.9923	***0.0001***
19b	143	103	2	3	259.0	202.5	153.5	NA	87.99	2	***0.0000***	1130.5	-7.3505	***0.0000***
20	143	103	2	4	319.0	277.5	238.0	195.5	85.64	3	***0.0000***	2370	-6.9972	***0.0000***
21	143	104	2	4	342.0	267.0	222.0	209.0	NA	3	***0.0000***	2378	-7.5410	***0.0000***
22	143	104	2	3	269.0	205.5	149.5	NA	112.59	2	***0.0000***	1128.5	-8.2858	***0.0000***
23	143	104	2	3	270.5	212.0	141.5	NA	125.48	2	***0.0000***	1119	-8.9445	***0.0000***
24	143	102	2	4	264.5	205.0	142.5	NA	116.76	2	***0.0000***	1102	-8.5417	***0.0000***
25	143	102	2	3	307.5	271.0	217.0	224.5	55.25	3	***0.0000***	2398.5	-5.1964	***0.0000***
26	143	102	2	1	168.5	227.5	280.0	344.0	145.74	3	***0.0000***	2839.5	9.2977	***0.0000***
27	143	101	2	4	342.5	275.5	210.5	181.5	155.64	3	***0.0000***	2251	-9.4445	***0.0000***
28	143	102	2	4	241.5	239.0	232.0	307.5	37.24	3	***0.0000***	2645.5	3.2756	***0.0005***
30	143	101	2	4	279.0	256.5	231.5	243.0	13.81	3	***0.0032***	2458.5	-2.2922	***0.0109***
31	143	101	2	1	165.5	221.5	277.5	345.5	156.18	3	***0.0000***	2823	10.2718	***0.0000***
33	143	102	2	4	309.5	275.5	223.0	212.0	94.19	3	***0.0000***	2377.5	-5.9167	***0.0000***

			LEGEND	Condition 1 ==> At Sea	S ==> Significant @ alpha level						
				Condition 2 ==> In Port	NS ==> Not Significant @ alpha level						
				Condition 3 ==> Shore Duty							
				Condition 4 ==> On Leave							
				alpha/2	**0.0500**	**0.0250**	**0.0100**	**0.0050**	**0.0025**	**0.0010**	**0.0005**
	Condition (i)			**Prob**	**0.9500**	**0.9750**	**0.9900**	**0.9950**	**0.9975**	**0.9990**	**0.9995**
Survey Question	**Condition (j)**	**difference**	**MyComp Output**	**normal quantiles qnorm ()**	**1.6449**	**1.9600**	**2.3263**	**2.5783**	**2.8070**	**3.0902**	**3.2905**
17a	1										
	2	52			S	S	S	S	S	S	S
	1										
	3	88			S	S	S	S	S	S	S
	1										
	4	160	10.43252		S	S	S	S	S	S	S
	2										
	3	36			S	S	S	S	S	S	S
	2										
	4	108			S	S	S	S	S	S	S
	3										
	4	72			S	S	S	S	S	S	S
17b	1										
	2	75			S	S	S	S	S	S	S
	1										
	3	95			S	S	S	S	S	S	S
	1										
	4	142	9.005997		S	S	S	S	S	S	S
	2										
	3	20			S	S	NS	NS	NS	NS	NS
	2										
	4	67			S	S	S	S	S	S	S
	3										
	4	47			S	S	S	S	S	S	S

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
18	1										
	2	33.5			S	S	S	S	S	S	S
	1										
	3	33			S	S	S	S	S	S	S
	1										
	4	39.5	7.75018		S	S	S	S	S	S	S
	2										
	3	0.5			S	S	S	S	S	S	S
	2										
	4	6			S	S	S	S	S	S	S
	3										
	4	6.5			S	S	S	S	S	S	S
19a	1										
	2	42			S	S	S	S	S	S	S
	1										
	3	72			S	S	S	S	S	S	S
	1										
	4	#N/A	8.593263		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2										
	3	30			S	S	S	S	S	S	S
	2										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
19b	1										
	2	53.5			S	S	S	S	S	S	S
	1										
	3	105.5			S	S	S	S	S	S	S
	1										
	4	#N/A	8.554325		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2										
	3	52			S	S	S	S	S	S	S
	2										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
20	1										
	2	41.5			S	S	S	S	S	S	S
	1										
	3	81			S	S	S	S	S	S	S
	1										
	4	123.5	11.97137		S	S	S	S	S	S	S
	2										
	3	39.5			S	S	S	S	S	S	S
	2										
	4	82			S	S	S	S	S	S	S
	3										
	4	42.5			S	S	S	S	S	S	S

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
21	1										
	2	75			S	S	S	S	S	S	S
	1										
	3	120			S	S	S	S	S	S	S
	1										
	4	133	11.55877		S	S	S	S	S	S	S
	2										
	3	45			S	S	S	S	S	S	S
	2										
	4	58			S	S	S	S	S	S	S
	3										
	4	13			S	S	S	S	S	S	S
22	1										
	2	63.5			S	S	S	S	S	S	S
	1										
	3	119.5			S	S	S	S	S	S	S
	1										
	4	#N/A	7.669445		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2										
	3	56			S	S	S	S	S	S	S
	2										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
23	1										
	2	58.5			S	S	S	S	S	S	S
	1										
	3	129			S	S	S	S	S	S	S
	1										
	4	#N/A	7.299089		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2										
	3	70.5			S	S	S	S	S	S	S
	2										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
24	1										
	2	59.5			S	S	S	S	S	S	S
	1										
	3	122			S	S	S	S	S	S	S
	1										
	4	#N/A	7.420536		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2										
	3	62.5			S	S	S	S	S	S	S
	2										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3										
	4	#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
25	1										
	2	36.5			S	S	S	S	S	S	S
	1										
	3	90.5			S	S	S	S	S	S	S
	1										
	4	83	12.70339		S	S	S	S	S	S	S
	2										
	3	54			S	S	S	S	S	S	S
	2										
	4	46.5			S	S	S	S	S	S	S
	3										
	4	7.5			S	S	S	S	S	S	S
26	1										
	2	59			S	S	S	S	S	S	S
	1										
	3	111.5			S	S	S	S	S	S	S
	1										
	4	175.5			S	S	S	S	S	S	S
	2										
	3	52.5	11.03744		S	S	S	S	S	S	S
	2										
	4	116.5			S	S	S	S	S	S	S
	3										
	4	64			S	S	S	S	S	S	S

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
27	1										
	2	67			S	S	S	S	S	S	S
	1										
	3	132			S	S	S	S	S	S	S
	1										
	4	161	9.870326		S	S	S	S	S	S	S
	2										
	3	65			S	S	S	S	S	S	S
	2										
	4	94			S	S	S	S	S	S	S
	3										
	4	29			S	S	S	S	S	S	S
28	1										
	2	2.5			S	S	S	S	S	S	S
	1										
	3	9.5			S	S	S	S	S	S	S
	1										
	4	66			S	S	S	S	S	S	S
	2		13.31926								
	3	7			S	S	S	S	S	S	S
	2										
	4	68.5			S	S	S	S	S	S	S
	3										
	4	75.5			S	S	S	S	S	S	S

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
30	1										
	2	22.5			S	S	S	S	S	S	S
	1										
	3	47.5			S	S	S	S	S	S	S
	1										
	4	36	13.20909		S	S	S	S	S	S	S
	2										
	3	25			S	S	S	S	S	S	S
	2										
	4	13.5			S	S	S	S	S	S	S
	3										
	4	11.5			S	S	S	S	S	S	S
31	1										
	2	56			S	S	S	S	S	S	S
	1										
	3	112			S	S	S	S	S	S	S
	1										
	4	180			S	S	S	S	S	S	S
	2		10.56346								
	3	56			S	S	S	S	S	S	S
	2										
	4	124			S	S	S	S	S	S	S
	3										
	4	68			S	S	S	S	S	S	S

				alpha/2	0.0500	0.0250	0.0100	0.0050	0.0025	0.0010	0.0005
	Condition (i)			Prob	0.9500	0.9750	0.9900	0.9950	0.9975	0.9990	0.9995
Survey Question	Condition (j)	difference	MyComp Output	normal quantiles qnorm ()	1.6449	1.9600	2.3263	2.5783	2.8070	3.0902	3.2905
33	1										
	2	34			S	S	S	S	S	S	S
	1										
	3	86.5			S	S	S	S	S	S	S
	1										
	4	97.5	9.642282		S	S	S	S	S	S	S
	2										
	3	52.5			S	S	S	S	S	S	S
	2										
	4	63.5			S	S	S	S	S	S	S
	3										
	4	11			S	S	S	S	S	S	S

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